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2017

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Chisebe, Khumbelo Britney (2017) Exploring potential impacts of hydraulic fracturing (fracking) on groundwater contamination in the Karoo: perspectives on institutional capabilities in water management in South Africa, University of the Witwatersrand, Johannesburg, <http://hdl.handle.net/10539/23493>

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Exploring potential impacts of hydraulic fracturing (fracking) on groundwater contamination in the Karoo. Perspectives on institutional capabilities in water management in South Africa.

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A thesis submitted in fulfilment of the requirements for the degree of
Master of Environmental Science.
with

Witwatersrand University, Johannesburg, South Africa,
(School of Geography, Archaeological and Environmental Science within the Faculty of Science)

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02nd June 2017

ACKNOWLEDGEMENTS

Glory to the Lord Almighty for he his faithful and has blessed me with ability to work hard and complete this research, through him all things are possible.

My gratitude goes to my supervisor Prof Danny Simatele for who was patient and supported me greatly throughout this work. Thank you for your constructive and critical comments on various drafts since the beginning of this project. You helped me improve my texts and research writing skills, I will forever be grateful.

I would like to use this opportunity to thank my father Mr Michael Chisebe for believing in me, calling me every week to encourage me on my studies. I am truly grateful to my wonderful siblings as I am the youngest in the family. To my sister Alleen Chisebe you raised me like your own daughter in the absence of our late mother, today I am a responsible strong woman because of you. To my two loving brothers Oscar Chisebe and Fulu Chisebe you protected and looked after my best interested to make it in life and be successful. Throughout this study you all understood the challenges I faced but you never gave up on me but continued supporting me. I love you all so much and I am always praying for you. To the love of my life Aluwani Ramalivhana, thank you for all your support and proof reading my work.

Thank you to all my friends for your love and encouragement. You were all kind to respect studying time and understood there was no time for hanging out at some point. All my friends who I encouraged to enrol for master's degree thank you for sharing the same vision with me, trust me you made me work hard to complete my studies before all of you.

I wish to express my appreciation to all people and institution which made it possible for me to carry out this study. I would like to thank all research participants who made this research successful by your insightful contributions towards the research. This project wouldn't have been possible without the assistance and participation of you all.

DECLARATION

I Khumbelo Britney Chisebe hereby declare that this dissertation is my own original work; all the sources that I have used and quoted in this study have been indicated and acknowledged in the form of reference. This study has not been and will not be presented for a degree purpose at another institution.

Signature_____ Date_____

ABSTRACT

Hydraulic fracturing in the Karoo is said to be a game changer of energy sector in South Africa, but it is said to pose potential groundwater contamination. Therefore the aim of the study was to investigate the extent to which current institutional set up in South Africa can deal and address potential environmental challenges that are associated to fracking. The study was particularly interested in investigating the institutional capabilities in the context of water management.

The literature review of this study showed that water resource is a major environmental concern that revolves around hydraulic fracturing, including the water resources use and potential contamination. In addition, it should be considered that hydraulic fracturing is a new mining process in South Africa and Africa as a whole with controversial mining techniques and environmental impacts involved within this process. The review indicates that the biggest issue with proposed hydraulic fracking mining process in the Karoo is if the South African Government has taken into consideration the resources, infrastructures and skills to execute the process successfully. The literature asserts that even if proper enforcement of any regulations on this rapidly expanding industry will still be difficult as the regulation is insufficient due to certain explicit exemptions. In South Africa, the starting point for hydraulic fracturing and the associated regulations that governs fracking, is the recognition of an argument that South Africa does not possess any fracking specific laws, guidelines or even polices.

Research participants were asked to give their views on the research topic by answering the semi structured interview questions. Data from the semi-structured interviews and literature review was analysed and discussed to address the research questions. The results of the investigation confirmed that there was no any legislation in place to govern this mining process in South Africa. Currently there are legislations which are under review and development to also address hydraulic fracking and the protection of water resources. The government should also involve other research institutes in the drafting and decision making of the legal institute governing hydraulic fracking to ensure that all gaps are identified before fracking can be permitted in the Karoo.

LIST OF TABLES

Table 3.1: Research study identified and interviewed key informants (Page 30)

Table 4.1: Participants knowledge on hydraulic fracking (Page 40)

Table 4.2: Participants key phrases to describe hydraulic fracking (Page 41)

Table 4.3: Participants view on whether hydraulic fracking will cause environmental impacts in the Karoo (Page 43)

Table 4.4: Potential environmental impacts that could emerge at the Karoo from hydraulic fracking (Page 45)

Table 4.5: Participant's opinion on whether fracking requires less or more water (Page 46)

Table 4.6: Hydraulic fracking lessons learnt identified by participants emerging from other countries already conducting fracking (Page 50)

Table 4.7: Required capacity for South African government to conduct fracking (Page 52)

Table 4.8: Participants view on whether or not hydraulic fracking will pose challenges (Page 53)

Table 4.9: Participants view on if the government is doing enough to keep the public informed about hydraulic fracking (Page 54)

Table 4.10: Potential benefits of fracking for the South African economic developments (Page 56)

Table 4.11: Mandated regulations to govern hydraulic fracking (Page 66)

LIST OF FIGURES & DIAGRAMS

Figure 4.1: Participants knowledge about hydraulic fracking (Page 40)

Figure 4.2: Pie chart representing potential environmental impacts from hydraulic fracturing process (Page 44).

Figure 4.3: Participants opinions on the amount of water required for hydraulic fracking operations (Page 47).

Figure 4.4: The required capacity for the South African government to conduct fracking (Page 52).

Figure 4.5: Participants responds to fracking campaigns (Page 54)

Diagram 4.1: A summary of participants views on anticipated hydraulic fracking challenges in the Karoo (Page 74)

LIST OF ACRONYMS

ANC	African National Congress
DEA	Department of Environmental Affairs
NEMA	National Environmental Management Act
I&APs	Interested and Affected Parties
EIA	Environmental Impact Assessment
SEA	Strategic Environmental Assessment
MPRDA	Mineral and Petroleum Resources Development Act
USA	United Nations of America
NERSA	National Energy Regulator of South Africa
PASA	Petroleum Agency of South Africa
AGAA	Astronomy Geographic Advantage Act
MHSA	Mine Health and Safety Act
NEMWA	National Environmental Management Waste Act
NWA	National Water Act
GSGI	Global Shale Gas Initiate
TCP	Trillion Cubic Feet
RSA	Republic of South Africa

TABLE OF CONTENTS

Contents

ACKNOWLEDGEMENTS i

DECLARATION ii

ABSTRACT iii

LIST OF TABLES iv

LIST OF FIGURES & DIAGRAMS v

LIST OF ACRONYMS vi

TABLE OF CONTENTS vii

CHAPTER ONE 1

FRAMES OF REFERENCE 1

1.1. INTRODUCTION 1

1.2. PROBLEM STATEMENT 2

1.3. RESEARCH QUESTIONS 3

1.4. RESEARCH AIMS AND OBJECTIVES 4

1.5. DESCRIPTION OF THE RESEARCH STUDY AREA 4

1.6. THEORETICAL CONSIDERATIONS AND LITERATURE REVIEW 5

1.7. SCOPE AND LIMITATIONS OF THE STUDY 7

1.8. METHODOLOGICAL CONSIDERATIONS 8

1.8.1 Research design 8

1.8.2 Population and sampling procedure 8

1.8.3 Data collection tools 9

1.8.4 Data analysis 11

1.9. ETHICAL CONSIDERATIONS 11

CHAPTER TWO 13

THEORETICAL CONSIDERATIONS AND LITERATURE REVIEW 13

2.1 INTRODUCTION 13

2.2 GLOBAL CONTEXT ON HYDRAULIC FRACKING 14

2.2.1 International perspective and trends on mining 14

2.2.2 Theoretical and historical background on hydraulic fracturing 16

2.2.3 Sustainable hydraulic fracking 18

2.2.4 Socioeconomic impacts and benefits of hydraulic fracturing 20
2.2.5 Environmental security 22
2.3 REGIONAL PERSPECTIVE 23
2.3.1 Resource intensity for hydraulic fracturing 23
2.4 LEGISLATIVE CONTEXT 24
2.5 CONCLUSION 26
CHAPTER THREE 28
METHODOLOGICAL CONSIDERATIONS 28
3.1 INTRODUCTION 28
3.2 DESCRIPTION OF THE STUDY AREA 28
3.3 RESEARCH PHILOSOPHY 29
3.4 RESEARCH DESIGN 30
3.4.1 Description of materials and data source 30
3.4.2 Study population and sampling procedure 31
3.4 DATA COLLECTION TOOLS 33
3.5 DATA ANALYSIS 36
3.6 METHODOLOGICAL REFLECTIONS 37
3.7 CONCLUSIONS 38
CHAPTER FOUR 39
EMPERICAL EVIDENCE 39
4.1 INTRODUCTION 39
4.2 POTENTIAL ENVIRONMENTAL IMPACTS OF HYDRAULIC FRACKING ON GROUNDWATER RESOURCES IN THE KAROO 39
4.2.1 Research participants interpretation and knowledge of hydraulic fracking process 39
4.2.2 What are the environmental impacts associated with hydraulic fracking? 43
4.2.3 Participant's opinions on the amount of water required for hydraulic fracking operations. 46
4.2.4 Lessons which can be learned from other studies in terms of groundwater contamination from fracking operations. 49
4.3 IMPLICATIONS OF THE FINDINGS OF THIS STUDY IN A WIDER CONTEXT, PARTICULARLY IN SUB-SAHARAN AFRICA 51
4.3.1 Significant public reaction with regards to fracking 51
4.3.2 Participants views on the possible hydraulic fracking challenges 53
4.3.3 The state or local government to address the public about fracking development 54

4.4 REVIEW OF POLICY AND LEGISLATION FRAMEWORK 60
4.4.1 Mineral and Petroleum Resources Development Act, (Act No. 28 of 2002) 60
4.4.2 National Water Act, (Act No. 36 of 1998) 61
4.4.3 National Environmental Management Act, (Act No. 107 of 1998) 64
4.4.4 Constitution of Republic of South Africa, 1996 65
4.4.5 Legislation and policy approach 66
4.5 Conclusion 68
CHAPTER FIVE 69
ANALYSIS AND DISCUSSION 69
5.1 INTRODUCTION 69
5.2 POTENTIAL ENVIRONMENTAL IMPACTS OF HYDRAULIC FRACKING ON GROUNDWATER RESOURCES IN THE CONTEXT OF SOUTH AFRICA 69
5.3 SIGNIFICANT PUBLIC REACTION WITH REGARD TO FRACKING PARTICULARLY IN SUB-SAHARAN AFRICA 71
5.4 WHAT LEGAL AND INSTITUTIONAL FRAMEWORKS EXIST ON GROUNDWATER AND REGULATE HYDRAULIC FRACKING IN GENERAL? 75
5.5 GAPS IN LEGISLATION 76
5.5.1 An overview of the research topic 77
5.6 CONCLUSION 78
CHAPTER SIX 80
CONCLUSIONS AND RECOMMENDATIONS 80
6.1 INTRODUCTION 80
6.2 SUMMARY OF THE RESEARCH KEY FINDINGS 80
6.2.1 Potential impacts of groundwater contamination in the Karoo 80
6.2.2 Perspectives on institutional capabilities in water management in South Africa 81
6.3 RECOMMENDATION OF FURTHER RESEARCH STUDY 82
REFERENCES 84
APPENDIX A 90
Schedule/ structure of the research dissertation 90
APPENDIX B 91
Participant information sheet 91
APPENDIX C 94
Interview questions 94
APPENDIX D 97

Ethics clearance certificate.....97

CHAPTER ONE

FRAMES OF REFERENCE

1.1. INTRODUCTION

Hydraulic fracturing or "fracking" refers to the natural gas extraction from shale reservoirs (Van Tonder, De Lange, Steyl & Vermeulen, 2013). Shale has low permeability and poses certain difficulties in resources extraction below it. Drilling is a possible way to reach these embedded resources below shale reservoirs (Arop, 2013). Knudsen, (2012) further elaborates that fracking is the process of pumping liquids at high pressure as a result of the expansion and cracking of the bedrocks where gas is stored. This gas is released and harnessed through the inserted fracking pipelines and transported to the surface. According to Knudsen (2012), fracking technologies have made possible the production of natural gas extraction in shale places that were once unreachable.

Fracking has gained popularity as a mining method of extraction of oil and gas beneath shale and has improved reservoirs permeability (Healy, 2012). Fracking existed since 1960s, but its expansion into the extraction of gas came to prominence in the early 2000's (Vermeulen, 2012). It is a method practised more in developed countries, such as the United States of America (USA) and Canada. The use of fracking as a mining method has expanded rapidly since 2005 in the USA. According to Cortney (2012), the USA used fracking in 90% of oil and natural gas mining. Therefore, this method of mining will contribute towards the improvement of USA economy energy for at least the next 100 years.

Healy (2012) highlighted environmental impacts of hydraulic fracturing on groundwater contamination and drinking water for both commercial and domestic use. Healy (2012) states that groundwater contamination is the single most threat that fracking poses as a gas mining method. There are serious concerns around the need to assess the implication of this method. Healy (2012) added and argued that the potential risk to groundwater comes from injected fluid and released natural gas which may pose a threat to water available.

Several studies have reported the increased controversy of fracking on the actual or potential impacts on groundwater resources as well as environmental degradation (Havemann, 2013, Knudsen, 2012; Vermeulen, 2012; Van Tonder *et al.,* 2013). Although, the USA and Canada experience could provide valuable possible lessons to draw tangible conclusions on the relationship between fracking and groundwater contamination, more investigations still needs to be done on this matter (Investigation of Hydraulic Fracturing: Report of the Working Group, Republic of South Africa, 2012).

According to Vermeulen (2012) oil and gas was explored in the Karoo South Africa during 1965 to 1975, and the shale deposit found was large as 485 trillion cubic feet (tcf). South African government recently became interested in mining this shale gas. Since 2011, the South African Energy and Mineral Department granted exploration rights to oil companies in the Karoo (Van Tonder, De Lange, Steyl, and Vermeulen, 2013). The hydraulic fracturing application in the Karoo, is looking at a total area which consists of three precincts: a western, central and an eastern precinct (Econometrix, 2012). So far there have not been any identified drilling sites within the precinct. Explorations in the Karoo involve the study of the area's geology and the shale gas potential before the drilling can start (Van Tonder et al., 2013). There are people and movements who are against the proposed hydraulic fracking in the Karoo. Currently the anti-fracking movement holds a moratorium over fracking in South Africa and want details and transparency on the fracking process; they are of the view that currently there are no legislations developed for fracking in the Karoo (Havemann, 2013).

1.2. PROBLEM STATEMENT

It has been argued that fracking is the 'future' for global energy production and national economic development (Cortney, 2012). In the developed world (USA and Canada), for example, fracking of natural gas has been embraced as a cleaner source of energy for its carbon footprint compared to coal. Therefore this source of energy has been proposed to be mined in the Karoo in South Africa, it is said to be a game changer in energy production in South Africa as the country currently faces the energy shortage challenges (Cortney, 2012). Challenges of fracking as the future of cleaner energy still need to be considered. Successful story of fracking

in the USA and Canada can be attributed to investment in technological and skills development (Cortney, 2014). Together combined, they provide the much-needed resources to help to extract the natural gas in a much safer way.

In the USA, the institutional and legal framework coupled with the technology and skills base in fracking industry have ensured the development of fracking within defined environmental boundaries (Cortney, 2012 and Healy, 2012). For South Africa, it has been proposed to adopt fracking as a mining technique to extract natural gas in the Karoo. The South African government has in the recent past granted mining companies to carry out explorations in the Karoo to identify gas reservoirs. This has been done in the hope of overcoming the current energy shortages the country is facing. Whilst fracking has been a successful story in the USA and Canada, there are serious social and environmental concerns that fracking poses in South Africa. Therefore, the question on whether South Africa, as a country, has institutional and legal framework within which potential fracking associated environmental challenges could be addressed.

Healy (2012), for example identifies groundwater contamination as the single most threat of fracking on the environment. Therefore, this study intended to investigate the institutional capabilities of the South African government if it is capable to manage fracking, how the legislation will protect and manage water resources from the possible potential contamination. This research study also needs to further find out which legislation is applicable to govern hydraulic fracking and if other legislations have to be considered or reviewed.

1.3. RESEARCH QUESTIONS

In the view of thematic focus, the following questions were developed to guide the research:

(i) What are the potential environmental impacts of hydraulic fracturing on groundwater in the Karoo?

(ii) What are the existed legal and institutional frameworks on groundwater and the environment to be addressed?

(iii) What are the implications of the studies finding in sub-Saharan Africa?

1.4. RESEARCH AIMS AND OBJECTIVES

The aim of the study was to look into the South African institutional set up in addressing environmental challenges associated with fracking. The study was particularly interested on the relationship between institutional capabilities and water management.

An inventory of the hydraulic fracturing environmental impacts on groundwater and its legal framework had the following objectives;

(i) Identify the potential impacts of hydraulic fracking in context of South Africa.
(ii) Evaluate the mandated key institutions that could address groundwater contamination associated to fracking.
(iii) To evaluate the extent to which contemporary environmental legislation can address issues of groundwater contamination resulting from fracking.

1.5. DESCRIPTION OF THE RESEARCH STUDY AREA

The study did not include the actual site visit to the Karoo, there were no actual drilling or fracking process taking place only the explorations during the time of the research study. A brief description of the Karoo; the Great Karoo covers around 400 000km^2 in the geographic midriff of South Africa stretching over the provinces of Eastern, Northern and Western Cape (The Great Karoo, 2014). According to Fox and Rowntree (2013) the Karoo lies on the southern drainage slopes of the great escarpment nearly on the southern coastline. It is a unique biome characterised as a pristine semi desert natural region forming a distinct geological division of the country (The Great Karoo, 2014). The Karoo is one of the driest areas in South Africa and faces serious water shortage. According to The Great Karoo (2014) water availability in the Karoo is limited and groundwater level is partially low. The rainfall ranges from 200mm/a year to over 1000mm/a year (National water resource strategy, 2014).

The geomorphology of the Karoo area is characterised as unspoiled landscapes, rich and special ecosystems with a variety of endemic species (Vermeulen, 2012). Karoo has “harsh temperatures and sparse vegetation of low, bushy trees” (Netshishivhe, 2014). There is little

information about the orientation of dolerite at depth greater than that typically reached by boreholes (Vermeulen, 2012). According to Vermeulen (2012), natural gas identified in the Karoo may have deposits as large as 485Tcf making it the fifth largest deposit in the world.

The Karoo has potential economic viable shale gas reserves and the future of fuel interest South Africa's hydraulic fracturing (Van Tonder, 2013). The current successful contribution of the Karoo economy has been through tourism, game farming and sheep farming being the dominant economic pursuit (Mentor, 2012). According to Mentor (2012), despite the potential economic contribution of fracking in the Karoo, the concern among residents and South African citizens is the potential impact of hydraulic fracking on groundwater quality. Most of the rural areas including some inland cities in the Karoo are dependent on groundwater for portable water supply (Van Tonder, 2013). The debate around the protection of groundwater resources in the Karoo motivated the interest on the research study.

1.6. THEORETICAL CONSIDERATIONS AND LITERATURE REVIEW

The study entailed the review of the legislations and policies applicable for the management and protection of groundwater from potential contamination caused by hydraulic fracturing. Throughout the world and particularly in South Africa, there are many discussions on the hydraulic fracturing in the Karoo; these discussions are based on the fact that fracking is a new mining technique in South Africa even in Africa as a whole. This technique interests different organisations which are curious on the controversial mining techniques and environmental impacts involved within this process. The literature provides a theoretical and historical background on mining, specifically hydraulic fracturing, its environmental implications, legal framework, its water management and sustainability.

According to the shale gas reservoir investigations, the USA is home to the largest known shale gas reservoir in the world. This natural gas now fuels nearly 40 percent of the country's electricity generation for over ten years (Natural gas fracking- introduction; 2015). Fracking has allowed USA to replace ten percent of coal which is used traditionally to generate electricity and this trend is expected to increase (Natural gas fracking- introduction; 2015). However primary

concern of fracking is the potential "damaging impact of natural gas drilling on water" [1] sources. This raises significant public health and environmental impact concerns.

Hydraulic fracturing explorations are taking place in the Karoo. Van Tonder (2013) and Vermeulen (2012) pointed out that groundwater contamination is the single most threat in South African as most areas are dependent on groundwater for portable water supply. In the lines of groundwater contamination being the most single threat, subsurface water contamination is an environmental issue from the types of mining (Mohr-Swart, 2008). Pollutants that infiltrate the surface and penetrate subsurface material contaminate groundwater (Van Tonder, 2013). The processes of intersecting shallow gas pockets; drilling of wells, flow back and produced water spills are the main causes of groundwater pollution from mining (Cortney, 2012). Normally, water contamination arises from mistakes in construction and operation (Van Tonder, 2013)

According to the Report of the Working Group on Investigation of Hydraulic Fracturing (2012), groundwater contamination can be expected within the mining process. The chances for hydraulic fracturing to affect adversely groundwater aquifers are as low as one in 200 million. This is because most underground aquifers are less than 1,000 feet deep, while hydraulic fracturing occurs up to 10,000 feet deep of which it is significantly below the water table (Consultancy Africa, 2015). According to environmentalists, the concern is not only on contaminating groundwater but with water used to perform hydraulic fracturing (Knudsen, 2012). Knudsen (2012) reported that a typical natural gas well, roughly 4.5 million gallons of water are used for hydraulic fracturing process. It is expected to increase with the growing production of natural gas. South Africa is deficient in water as country and a dry area, therefore a sacrifice of millions litres of clean water will be required for a single well (Van Tonder, 2013).

Mohr-Swart (2008) noted that different mining processes have impacts on the environment and the regulation that governs the minerals' exploitation. The National Environmental Management Act (NEMA) and the (Mineral and Petroleum Resources Development Act (MPRDA) has become increasingly aware of activating sustainable mining to protect the environment. NEMA regulates, enforces and has jurisdiction over environmental management impacts. According to

[1] http://www.gracelinks.org/191/natural-gas-fracking-introduction

Mohr-Swart (2008), NEMA has imposed the cost-efficient compliance with environmental law and self-imposed environmental policies to ensure continual sustainability for mineral use and to protect the environment. Karoo communities want to be assured that after abandonment and closure of a gas well, the company will still be responsible if pollution of water takes place (Van Tonder, 2013).

1.7. SCOPE AND LIMITATIONS OF THE STUDY

Mining involves different types of mining processes; this study focused on a new mining technique of shale gas fracking which is proposed in the Karoo South Africa. The goal of this research was to explore hydraulic fracturing impacts of on groundwater contamination and the capacities of the institutes of South Africa in water management. This analysis will define exact mandated institutes responsible for the whole fracking processes. The aim was not to compare the identified fracking environmental impacts related, but explore the capacity of South Africa' institutional set up to address environmental challenges associated to fracking.

The study did not include the actual site visit to the Karoo. There was no drilling or fracking process taking place at the time of the research but only the explorations. The research acknowledges the limitations of visiting the actual fracking exploration site, given that there was no access to communicate with people involved in the project. Given the short time period, there might be a number of constraints that would shape the interview with the participants and the outcome of the research. For the identified research participants who are directly involved or situated in the Karoo, interview questions were emailed to them. Theoretical saturation concluded the period of the research. Theoretical saturation is the reach of strong narrative themes to further be analysed began continually emerging (Cater, 2013).

The study focused on the review of the South African legal framework related to fracking. It has been stated that hydraulic fracturing is a new mining process in South Africa and many other countries except for USA and Canada which have more than 10 years of fracking experience. This was a limitation as there was no much literature available and published on fracking. Therefore the forward move on literature review was to review and look into the legal

framework of the other countries which are already practising fracking such as the USA and Canada.

1.8. METHODOLOGICAL CONSIDERATIONS

The purpose of this section is to explain the steps which were followed to conduct the research. Camarinha-Matos (2012) describes methodology as the study of methods involved in a field of investigation or in a problem solving by following a codified series of steps taken to complete a certain task or to reach objectives. The research was conducted with the participation of the mining expects. This was done to select participants that would assist with an inside perspective and give their own experience related to the reteach study.

1.8.1 Research design

Makuluma (2011) describes research design as a plan or an outline on how one intends to conduct research while focusing on the end product based on the result aim. This chapter presents sections of methodological approach to the study. The first section discusses the hydraulic fracturing impacts on groundwater contamination. The research also examined the perspectives on the institutional capacities in water management in South Africa. The institutional capacities review was conducted through the studies of comparative literature surveys.

1.8.2 Population and sampling procedure

Bless and Higson-Smith (2000) describe a population as the entire set of objects or people that form the focus of the research on which the researcher intends to determine some characteristics. For the purpose of this study, the population included officials from energy and mineral department, water department, geology and geophysics representatives, trade industry, petroleum representative and the environmental activists. The study sample required people particularly

knowledgeable in the inquiry setting of the research study and articulated about their knowledge and experiance.

Qualitative research is a type of scientific research which aims to seek answers to questions, collect evidence and produce findings that were not determined in advance (Qualitative Research Methods: A Data Collectors Field Guide, 2005). Data was collected using purposive and snowball sampling, where target key informants gave answers to the designed fracking related interview questions. To explore some phenomenon experienced by the research participants, it was found necessary to purposely select individuals or group of people who meet specific criteria of the study (Patton, 2002).

The sample size might change depending on the resources, time availability as well as the study's objectives. Key informants were selected purposely based on the following criteria:

i. An experienced and knowledgeable personnel's with at least 5 years' experience within their specific departments mentioned above.
ii. Specific interest group on hydraulic fracturing

A list of all key informants with relevant specialities or knowledge in the research topic was compiled. The telephone or email was used to invite individuals or organisations to participate in the study. The invitation to each individual or organisation was provided with the information about the research project and their importance in accepting the invitation. For all individuals who confirmed participation to the study, the interview was scheduled according their availability and convenience about time and place. For any identified key informants based in the Karoo where the hydraulic fracturing is occurring or any other parts of the country, which face-to-face interview could not be impossible, the interview questions were emailed to them.

1.8.3 Data collection tools

Data collection is an important part of the research study, it involves gathering of relevant information of the study through different methods. The study was carried out using the following data collection tools:

a) *Interviews*

Semi-structured interviews serve as a semi-formal conversation between key informants and the researcher (Cater, 2013). The flexibility of the interview helped the researcher to probe deeper where relevant information could only be obtained through further questioning. If the participant referred the researcher to another key informant (snowball), the key informant would participate in the study according to their availability.

The questionnaires were structured for participants to give an outline on any knowledge of fracking, about fracking potential contamination of groundwater, participants' thoughts, knowledge about institutes appointed for water management responsibility, any review on the legal framework to cover hydraulic fracturing in the Karoo, and what are the `participants' expectations on fracking and any other related plans.

b) Historical profile (literature review)

The other basic research procedure used for the project was the historical profile procedure (Literature study). History and current debates on fracking was limited on the South Africa's context but with reference of other countries. Themes included in the study are the mining history, hydraulic fracturing, environmental management, sustainability, the legal framework and the South African mandated institutes on the issue of fracking. The review of secondary data was based on textbooks, published works, periodicals, newspapers, popular articles, corporate reports, conference proceedings, journals and applicable legislation.

The study of the legal and institution framework related to hydraulic fracturing and water management would require detailed reading to find the existence of correlated regulations to the proposed hydraulic fracturing in the Karoo. Compare existing water regulations to those of the mine regulations implemented for the protection of water bodies. The study of regulations was based on Mineral and Petroleum Resources Development Act 2002 (Act No. 28 of 2002), National Environmental Management Act 1998 (Act No. 107 of 1998), National Water Act, 1998 (Act No 36 of 1998), Waste/ waste water management and other relevant regulations and policies.

c) Observations

Observation is a fundamental way to find out details of the environment around us by using our senses engaging brain, eyes and ears to make sense of data being collected (Fox, 1998).

Observations were recorded from interviews and people's views concerning the issue of hydraulic fracturing and the potential of groundwater contamination in the Karoo. The research observed the attributes of events and actions affecting the observed view during interviews. Reasons might be associated with the interviewee and their background, the culture and the interpretation of the situation. Observations were made on the attitude and prejudice people on the new proposed hydraulic fracturing in the Karoo and the potential of groundwater contamination.

1.8.4 Data analysis

Collected information from qualitative semi-structured interviews and historical profile were imported into Microsoft Excel spreadsheet, for first screen erroneous data. Collected data was analysed using thematic content analysis. All the transcripts were read, highlighting the keywords, themes and ideas found within the scripts to determine patterns of repetition and information that was abstract to the research. Then the remaining required information on the scripts was then imported into Microsoft Excel spreadsheet, to first screen for erroneous data.

1.9. ETHICAL CONSIDERATIONS

Research ethics safeguard the research participant's interest; therefore ethics was abided with throughout the whole research as it involves participation with people and relevant document analysis. The project proposal and the consent forms to conduct the research abided with the ethics policy of the University of Witwatersrand prior to beginning of all fieldwork activities involving interviews to ensure that the research subject was not deceived. Participants of the interview were requested to sign the prior informed consent form and they were informed about the aim, purpose and the procedure of the research study to ensure that they are not deceived in any way. The research was designed to ensure that there will be no physical or psychological harm suffered by the participants as a result of the study.

Voluntary participation was kept by ensuring that the research participants were made aware of their rights and ensure they feel comfortable with interview content and setting (Cater, 2013). No participants were forced to participate in the research and they were given the right to withdraw from the research at any given time. All information gathered during the research was dealt with confidentially. Permission from the participants to publish information will be obtained for all information.

CHAPTER TWO

THEORETICAL CONSIDERATIONS AND LITERATURE REVIEW

2.1 INTRODUCTION

This research intends to review existing theories and literature in order to understand the view on potential impacts of hydraulic fracturing on groundwater contamination in the Karoo. It is important to view the theories and existing literature on hydraulic fracturing as it is a new proposed mining technique in South Africa which is said to be the new energy source supply. It is important to establish whether the literature undertaken address the research problem of the study. This literature analysis is coupled with an approach of addressing the fracking activities from both the resources use and resource impacts. These include potential water contamination, it is also necessary to understand the perspectives on institutional capabilities in water management in South Africa with regard to fracking.

With reference to this study, there is a brief discussion between the global and regional context on the perspectives and trends of hydraulic fracking. Looking at the global context, this section continues to look at the theoretical and historical background on hydraulic fracking. This discussion highlights the international perspective and lesson learnt on hydraulic fracking together with the capital intensity required and looking at the environmental impacts of hydraulic fracking.

The regional context looks at the proposed hydraulic fracking in the Karoo South Africa. The final section which is section three, discusses the legislative context and spatial planning policy. The section looks at the approach policy learning and the study regulation of the shale gas extraction. The discussion on this section, assess if the South African government has the required capacity to conduct hydraulic fracturing. This chapter defines theoretical frameworks and related concepts used to ascertain the South African government regulations of the shale gas extraction. The last section is the conclusion of the literature review.

2.2 GLOBAL CONTEXT ON HYDRAULIC FRACKING

2.2.1 International perspective and trends on mining

According to Nooten (2007) mining is an inherently unsustainable activity which is based on the exploration for and development of non-renewable resources. Nilsson & Randhem (2008) further elaborates that the choice of extraction method is based on the characteristics of the mineral, safety and environmental concerns, technology and economics. The most traditional methods are surface mining and underground mining. This explains why hydraulic fracking is viewed as the new mining method involving the horizontal drill. Moreover, Nooten (2007) sees the mining industry as production cycle that turns non-renewable resources into a profit. This profit can contribute economically to sustainable development of countries. This is a reason to why mining has been explored in various ways that the ongoing legacies of mining industries persist in both the physical environment and the social of communities. Nooten (2007) elaborate that, usually mining are characterised as process that brings change of effect within a certain environment.

Nilsson & Randhem (2008) elaborates the change brought forward by mining as the three main categories which are distinguished as a result of mining: change in the natural topography which results in restrictions in the possibilities of using the land for other purposes, changes in the hydrogeological conditions with consequences for both groundwater and surface water. Finally is the change in the geotechnical conditions of the rock. This cause adverse change in the biosphere and is mainly affected by pollution and by degradation of land and vegetation resulting in loss in biodiversity (Nilsson & Randhem, 2008). Nooten (2007) further adds that the impact varies with local conditions of the specific site of mining. The change brought forward by mining can be sustainable development or the environmental impact which is why there is bad history across the globe that once the mining process is completed or closed out: the remnants of processes of mineral extraction are left for the neighbouring communities to deal with thereafter. These changes caused by mining can give rise to various impacts on the geoenvironment, described below.

The potential negative environmental impacts caused by the mining processes have been in existence since the beginning of mining industry Nooten (2007). However the impacts are

determined by the type of material being produced and on the mining operation. Nilsson & Randhem (2008) further elaborate on some of the negative environmental impacts such as atmospheric emissions during mining, occur not only from internal combustion engines in mining machinery but dust and gases are also released from blasts and rocks and mineral masses. Furthermore to environmental negative impacts caused by mining processes is the use of smelters which are commonly used for mineral purification and emissions from these processes include particulate matter and gases such as sulphur dioxide, carbon monoxide and carbon dioxide (Nilsson & Randhem, 2008). Although some installations use different kinds of flue gas purifications, these are never completely effective. Physical hazards include noise, heat, vibrations, falls and explosions, flooding and various forms of dust, aerosols and fine particles with resulting fibrogenetic and carcinogenic effects.

Fischer-Kowalski and Swilling (2011) states that among most of the mining activities the most pressing environmental impacts has always been energy and water use. This is caused by the creation of mine waste with toxic emissions leached to the under groundwater table causing contamination. Nilsson & Randhem (2008) indicates that chemical hazards which arise from chemical pollutants in water, solid wastes and air with the most common substances being carbon monoxide and dioxide, oxides of sulphur, nitrogen oxides and fluorine compounds. The water table contamination includes tailing dam failure, deep water disposal and disposal of contaminated water into the rivers. Other water bodies also include the acid mine drainage which is sulphides in water (Fischer-Kowalski and Swilling, 2011).

Most of mining firms increase the amount of energy generated by coal and petroleum derivatives, whose emissions contribute to global warming and the climate change. These excessive emissions drove the mining companies to bring innovative and sustainable ideas to reduce emissions of toxic substances and the air pollution from smelting, combustion processes of the ore (Roberts, 2013). It has been noted that air quality in the vicinity of mines is extremely fragile and must be monitored and maintained safely. The sustainable use of water resources in the mining sector poses a challenge by the intensive use of water during the extraction process (Fischer-Kowalski & Swilling, 2011). Makululuma (2011) indicates that the “inter-basin water transfers, in South Africa, have degraded the ecological integrity of aquatic systems. Heavy

metals and sulphates from mining activities have polluted valuable water resources. This indicates that the combination of low average rainfall, overexploitation and re-engineered spatial flows have led South Africa to water crisis in quantity as well as quality. Fischer-Kowalski and Swilling (2011) agreed that most mining companies are getting involved in the sustainable mining procedures. So, they are correcting bad practice from the existing water supplies and ensure surrounding communities have safe drinking water.

2.2.2 Theoretical and historical background on hydraulic fracturing

Shale gas development has a long history in terms of oil production in the world. According to Mentor (2012) the first commercial natural gas well that produced shale gas was recorded in the 1821 in Fredonia, New York. During this time, there were various methods used to get natural gas only until in the late 1940s that hydraulic fracturing was first used to stimulate oil and gas wells (Mentor, 2012). The development did not stop there, the mining technology continued in the 1980s and 1990s when Mitchell Energy and Development Corporation combined large fracture designs including horizontal drilling and low cost approach to hydraulic fracturing. This was developed as an attempt to make the use more economically viable for shale gas production. Furthermore recent improvements in technology of hydraulic fracturing have made it possible for shale gas to be extracted from sites that were not previously viable. Roberts (2013), states that the horizontal drilling and slick water hydraulic fracturing was used to crack the shale rock opened.

According to the World Energy Council (2010), there are over 688 recorded shales worldwide, located within 142 identified basins. USA is home to the largest known shale gas reservoir in the world with the largest known production potentials (Natural gas fracking- introduction, 2015). It is estimated that as many as 35 000 wells are fractured annually in the USA as the hydraulic fracturing technology continues to improve (US DOE, 2011). This natural gas now fuels nearly 40 percent of the country's electricity generation for over 10 years (Natural gas fracking-introduction, 2015). Fracking allowed USA to replace 10 percent of coal used traditionally for electricity generation, which the trend is expected to increase (Natural gas fracking- introduction, 2015). With the expected increase in hydraulic fracking trends, natural gas is said to be a

transitional fuel of future clean energy that will help replace conventional mineral and oil. In addition, shale gas has an increased role in the global energy mix and energy security.

The large amount of water required for hydraulic fracking contributes to the environmental impacts. Mentor (2012) discusses hydraulic fracturing as a process that requires large amounts of water to fracture the shale rock formations. This process requires water between 300 000 litres and 6 million litres per borehole (± 95%), sand (± 4.5%) and chemicals (± 0.5) (Cortney, 2012). The great pressure is pumped to create cracks in the shale rock formations to ease the gas flow. It is argued that hydraulic fracturing pose high potential environmental risks as compared to the older mining drilling techniques which only used less equipment, less water and produced less waste (Natural gas fracking- introduction, 2015).

However water resource is a major environmental concern that resolves around hydraulic fracturing, including the water resources use and potential contamination. The amount of water used in the fracturing process comes from various sources such as rivers, lakes, oceans or from local boreholes. However, the large water taken from streams is associated to significant impacts such as alteration of flow (for streams), depth, temperature and mineral chemistry (Mentor, 2012). Pepino (2014) further adds that the environmental risks to water levels, decreasing in an aquifer, are related to water quality with an impact from mineral content changes and salinity of the water. These affect the solubility, mobility, salinity and bacterial growth of an aquifer system (Cortney, 2012). This water is usually withdrawn continuously not allowing the aquifer to recharge. The control of water withdrawal permits is required for water wells that support oil and gas operations. However, the assessment of the limit on the amount of water to be withdrawn is difficult (Mentor, 2012). Natural gas fracking- introduction (2015) asserts that even any proper regulation's enforcement of an expanding industry will still be difficult. The reason is that the Safe Drinking Water Act and the Clean Water Act regulation are insufficient due to certain explicit exemptions of Energy Policy Act of 2005 (Natural gas fracking- introduction, 2015).

According to the Committee on Energy and Commerce (United States House of Representatives) (2011), fracking companies used over 2500 hydraulic fracturing products between year 2005 and 2009. The composition of products used varied by shale structure. Each chemical had its own design to achieve certain performance. According to Western Organisation of Resource Councils, 2009; New York State Water Resources Institute (2010) several of those chemicals

were found to be harmless but others pose serious risks to human and the environment. These chemicals are initially injected with the fracking fluid and contribute to highly toxic waste water return to the surface after fracturing. Cortney (2012) informs that only 10 percent of wastewater is recycled in Texas. The majority of it is stored on site in large storage pit until trucked to a deep well site for hazardous material.

Cartwright (2013) is of the view that potential contamination of underground sources of drinking water and surface waters results from spills and faulty well construction. Therefore there are adverse impacts from discharges into surface waters or from disposal into underground injection well. Funke (2013) asserts that the biggest concern of methane leaks is associated with extraction, production and transport of natural gas. Funke (2013) further adds that methane is a very potent greenhouse gas and the harm from significant fugitive emissions is not contested and no comprehensive data exist on the amount of methane escaping from well sites.

Another area of concern which has the potential to contribute to groundwater contamination is the waste transport and management. Funke (2013) is concerned that large amounts of water flow to the surface after fracking operations. Some of this water is returning frack water which is injected as part of the extraction process (‘flowback’). In addition, groundwater with chemicals, minerals, including dense brine, and often with radioactive elements from deep underground comes to the surface (Cartwright, 2013). The water coming back to the surface is contaminated with many different chemicals used for the fracking injection. Estimates for the percentages of returning waters vary tremendously, depending upon the volume of injected frack water and the formation. Funke (2013) explains that contaminated flowback and produced waters pose risks related to improper handling onsite, spills, leaks, accidents in transport, and improper or inadequate disposal.

2.2.3 Sustainable hydraulic fracking

According to Mentor (2012) shale gas industries are aware of the environmental risks involved with the drilling process of fracking. Mentor (2012) adds that the environmental impacts on the water resources are closely regulated, these events include water withdrawal, the subsequent storage, handling and treatment of water and waste fluids. There are sustainable measures used

during the hydraulic fracturing process to control the potential contamination of groundwater. This includes the flow back water that returns to the surface during the drilling process; often reused during the hydraulic fracturing process, with the rest sent to the surface, stored and treated (Riha & Rahm, 2010). Historically in the USA, flow back water and produced water were treated at permitted publicly owned wastewater treatment plants or disposed of into underground injection wells (Rahm, 2010). Rahm (2010) state that due to the large volume of water and high concentrations of dissolved solids prevalent in the hydraulic fracturing process, neither option would be adequate. Riha and Rahm (2010) recommended the use of temporary water treatment plants that are specifically designed for treating water from shale gas operations.

Riha and Rahm (2010) indicated that regulators play a significant role in terms of the implementation of precautionary steps as well as appropriate separation of drilling fluids and drinking water**"**. There are established regulations which are intended to influence the pace and scale of gas extraction activities through established permitting and compliance systems (Riha & Rahm, 2010). Pepino (2014) asserts that these events may occur at or below the surface due to leaks and spills which have serious impact on water resources and the surrounding environment. Although chemicals only constitutes 0.5 percent of the total volume of fracturing liquid, its effect on the environment when spilt, can be harmful if released into aquifers and other water bodies (Pepino, 2014).

Therefore regular monitoring of water sources in the fracking area can be a good measure to control the water contamination risks. Riha and Rahm (2010) show that baseline water testing is important and should be done before the exploration activities commence. For best control and monitoring procedures, the oil industries should be mandated to test water in areas identified as potential locations for hydraulic fracturing throughout the project cycle. Pepino (2014) suggested that correct procedures and practices have to be followed during the cement jobs and well casing construction. Hence, this will reduce fluid movement from deeper fracking wells to groundwater aquifers. According to Pepino (2014), "Alaska and Ohio are the two states known for the verification methods to monitor and demonstrate the quality of bonding between cement within the well". They verify if the well casing meets quality requirements for groundwater protection.

In addition to the fracking well, monitoring plugging is a good practice. Pepino (2014) further informs that this method is used in the fracking operations to seal the inside of the well after the shale gas extraction is completed. Well plugging is used in attempts to stop/reduce fluid migration, both horizontally and vertically. The best practices used currently in the fracking operations are the cast iron bridge plugs, capped with cement. This cast iron creates a strong seal for the well, and the cement layer is used as a mechanism of reducing the rate of corrosion (Pepino, 2014). Christina (2013) states that proper containing or treatment of hydraulic fracturing waste water is essential to control or prevent groundwater contamination. Depending on the physical characteristics of the well, 30-70% of the injected fluids have the probability of returning to the surface through the drilled wall (Christina, 2013). This is depended on the amount of fluids trapped within the fractured formation. This occurs as a result of fractures extended beyond the target formation. Furthermore, water migration and water seepage can act as transport agents of these chemicals which can move for miles into water sources (Christina, 2013).

2.2.4 Socioeconomic impacts and benefits of hydraulic fracturing

Mentor (2012) defines the socioeconomic status of a society as the interaction between the social and economic aspects of the society. It includes the aspects such as the demographics, age, rational composition and the economic aspects such as unemployment rate, income and savings. The review took into account the socioeconomic impacts on other towns or countries where fracking has taken place and assesses how the findings can be applied to the Karoo. It further assess how hydraulic fracturing as it is currently understood as well as how this mining industry has influenced the current socioeconomic at global, national and local scale.

Hydraulic fracturing mining process has the potential to create long and short-term diverse skills. It is a specialised mining technique except for drivers and general construction labour. Jacquet (2011) stated that the nature of gas industry, particularly in the hydraulic fracturing processes requires specialised subcontractors who already have experienced people in place to perform the work. These contactors in the drilling process are commonly the large energy companies who own the leases. Therefore, other services are contracted from companies such as drilling, well

completion, excavators, water hauling and cementing. In addition, Mentor (2012) indicates that employment opportunities are legible for the resident communities.

Through the study conducted by Natural gas fracking- introduction (2015) the USA shale gas industry has created approximately 600 000 jobs in 2010. USA is the largest country known for its shale gas reservoir in the world. According to Natural gas fracking- introduction (2015) it is estimated that by the year 2035, the USA shale gas industry will create more than 1.6 million jobs. According to Negai *et al.* (2012), the USA has been an example to other parts of the world and it is encouraging this effort by establishing partnership with other countries which have or intend to conduct hydraulic fracturing. According to the Natural gas fracking- introduction, (2015), in 2010 the USA government initiated a programme called the Global Shale Gas Initiate (GSGI). This programme aimed to help and transfer expertise to other countries and teach them about the shale gas industries (Natural gas fracking- introduction, 2015). This initiative was meant to share information on the laws and regulations that exist in the USA to achieve effective shale gas development in other countries. Natural gas fracking-introduction (2015) identified China and Poland as some of the countries which welcomed gas expertise initiative offered by USA. Countries such as China is continuously making progress in its shale gas development by attempts learnt from the USA. Poland is also developing and fostering relationships with USA to aid their shale development. USA operations companies assisted India in the implementation of shale projects with the shale gas exploration and production technologies (Natural gas fracking-introduction, 2015).

Jacquet (2011) reported that USA resolved the issue of foreign countries accumulating skills with fracking experience by implementing local workforce programmes. Local workforce programmes assisted local employees in finding work appropriate to their skills within hydraulic fracturing mining. Generally, the gas industry requires skilled specialised labour, which is why most of the industries already have their experienced people in place (Negai *et al.*, 2012). This is why most of fracking companies employ non-local workers as they are considered veterans in their fields. Local communities can be involved in the project if the fracking companies are obliged to implement training and development programs as part of their leases. In the case the fracking companies train and develop local people; then they can create stable jobs (Mentor,

2012). Usually, local residents find relatively few job opportunities and stable employment because of the lack of skills and experience.

2.2.5 Environmental security

Across the United States, Europe and Australia, diverse protest groups are emerging which take issue with the environmental consequences of the increased use of fracking in unconventional gas extraction (De Rijke, 2013). This kind of protect have been evident in South Africa on occasional cases leading to the formation of movements who are against the proposed hydraulic fracking in the Karoo (Havemann, 2013). According to De Rijke (2013) the anti-fracking movements across the globe share concerns about issues such as the industrialization of rural landscapes, food production, multinational corporate enterprise and community disempowerment, the potential for subterranean and surface water pollution, and future human and environmental health generally. De Rijke (2013) further adds that unconventional gas extraction requires a greater density of wells (one or more per square kilometre) and thus much more infrastructure, including well pads, pipelines, compressor stations, processing plants, roads, and water treatment facilities.

Looking into the scale of all activities and equipment's required for hydraulic fracking operations has caused concern about its environmental impacts, including major changes to the landscape (De Rijke, 2013). Widespread public concern about the impacts of this industry have emerged, particularly with regard to fracking, surface and subterranean water, air pollution and a host of other environmental, social and health issues.

Cartwright (2013) is of the view that regardless of 'protects' against hydraulic fracking, unconventional gas has been brought into production in many regions despite a poor understanding of its various potential impacts. Hydraulic fracking companies rely on technologies which may be invented or adjusted to help contain and mitigate the adverse effects of its deployment on the societies where it operates. Nevertheless, disputes about the potential social and environmental impacts of this technology may not be fully contained (De Rijke, 2013). However while gas development continues, opposers are forced to find risks acceptable,

exaggerated or likely to decline with evolving industry experience and technology (Funke, 2013).

(De Rijke, 2013) asserts that the health implications of fracking are under-researched there is much not known yet about the chemicals used in the process will affect human, animal and plant life. In addition to the health impacts, Funke (2013) identifies noise, dust, emissions and naturally occurring radioactive mineral (NORM) contamination levels will differ at different stages and locations and can be controlled under existing legislation. Investigation of Hydraulic Fracturing: Report of the Working Group. (2012). Funke (2013) is of the view that the role in protecting human health and environment, its tools are primarily statutory authorities which gives responsibility for identifying environmental threats and options for avoiding or mitigating the risks.

The major concerns of environmental impact of shale gas are on exploitation on land use, water use and air pollution. These impacts are covered on the existing environmental regulations, but an immediate and important concern requiring additional attention is water usage and disposal: in particular, the volume and transportation of the water, the potential contamination of water resources and the disposal of 'used' fracturing fluid. Investigation of Hydraulic Fracturing: Report of the Working Group. (2012).

2.3 REGIONAL PERSPECTIVE

2.3.1 Resource intensity for hydraulic fracturing

Southern Africa mining industry has existed for more than 100 years with minerals being the corner stone of the economy (Mohr-Swart, 2008). Mohr-Swart (2008) further elaborates that the mining industry in this region is complex, with different types of minerals and mining operations. Vermeulen (2012) asserted that shale gas has been in existence for long in South Africa. During 1965 to 1975, Soekor explored oil and gas in the Karoo, which has a shale deposit as large as 485 trillion cubic feet (tcf) (Vermeulen, 2012). The presence of shale gas in the

Karoo is expanded in the southern African region; with Mozambique around 130 tcf; Tanzania 45 tcf, Angola 12 tcf and Namibia at least 5 tcf (Consultancy Africa, 2015).

However, it should be considered that hydraulic fracturing is a new mining process in Southern Africa. The biggest issue with proposed hydraulic fracking mining process in the Karoo South Africa, is the involvement of South African Government in terms of resources, infrastructures and skills. Negai et al. (2012) concluded that all the processes applied in the USA environment cannot necessarily be replicated within other countries. South Africa cannot necessarily adapt all the legislations and hydraulic fracking processes from the USA. Nevertheless, there are most definitely lessons to be learnt as a reference for the shale gas developers.

An international oil company Shell Exploration Company has applied to explore the vast shale beds of the Karoo in South Africa. According to Golder Associates, (2011) there are many affected parties, who have interest in the Karoo hydraulic fracturing debate. Golder Associates (2011) is of the view that most controversial aspect of hydraulic fracturing process has to do with the scarce water resources of the arid and semi-arid Karoo biome.

"The *Mineral Resources Minister is responsible for ensuring the sustainable development of the country's mineral and petroleum resources; their development within the framework of the national environmental policy; while promoting socioeconomic development"* (Section 3, MPRDA, 2002). The "Mineral Resources Minister holds the power to designate a state-owned or a state–controlled company as the authority on mineral resource development (Section 70, MPRDA, 2002). Hydraulic fracturing has been highly debated by the oil and gas industry, regulators, legislatures, academics and environmental organisation for the past few years. In South Africa fracking is interrelated to issues such as economics, energy supply, environmental sciences and public health. The South African government will still have to decide whether to permit fracking or not, either way there would be criticisms on the decision made.

2.4 LEGISLATIVE CONTEXT

Any industry should operate under conditions where legislative clarity and regulations are certain; this also applies to the oil and gas industry. South Africa currently in a state of not

holding any of legislative for hydraulic fracturing. The starting point for hydraulic fracturing and related regulations is the recognition that South Africa does not possess any fracking specific laws, guidelines or even policies (Havemann, 2013). It should be considered that hydraulic fracturing is a new mining technique in South Africa, with no actual drilling taking place in the Karoo just only the explorations.

According to Havemann (2013) the following departments regulate oil and gas exploration and production: the Mineral and Petroleum Resources Development Act (2002) (MPRDA); the National Environmental Management Act (1998) (NEMA); the National Environmental Management Waste Act (2008); the National Water Act (1998) (NWA); (NEMWA); the Mine Health and Safety Act (1996) (MHSA); and the Astronomy Geographic Advantage Act (2007) (AGAA) (Department of Mineral Resources, 2012 (a)). *Petroleum Agency of South Africa* (PASA) is the first agency, as MPRDA, to regulate the exploration and development of oil and gas resources in South Africa (Havemann, Glazewski & Brownile, 2011). Furthermore, other important agencies in the facilitation of shale gas includes; the Department of Mineral Resources (DMR), and the Department of Water and Environmental Affairs.

However, South African legislature is currently under review of hydraulic fracking specific legislation. Although there are still debates if whether fracking should be permitted or not. Havmann (2013) is of the view that South Africa needs more than just a fracking specific regulation. Havmann (2013) further argues that the authority should be inconsideration to introduce more set of legislation in the future to accommodate technological advancements of fracking. Numerous changes will be required on the existing regulations that will cater for and affected by the introduction of regulations specific to hydraulic fracturing. Havmann (2013) argued that shale gas is a fuel product and could fall under the definition of petroleum in the MPRDA. NEMA does not address any fracking-related environmental concerns. South Africa needs an environmental legal framework to be adequately regulating the shale gas industry. There is a need of the amendments to the Gas Act to allow "an expanded role for the National Energy Regulator of South Africa [(NERSA)]. This will intended to create a platform for the development of potential shale gas resources projects in South Africa (Odendaal, 2013).

All the amendments and the drafting of regulations specific to hydraulic fracking are governed by the Section 44 of the Constitution (Roberts, 2013). The South Africa government could be described as a type of federal system of government, with the decentralisation of state power based upon the principle of cooperative governance. The African National Congress (ANC) a single political party that has dominance at the national level, even provincially (De Villiers, 2008). Furthermore, parliament possesses the power to assign its legislative powers; however this political party poses powers that may intervene on the legislation produced by these other legislative bodies by passing legislation to maintain essential national standards. The Karoo community is mostly against fracking which is anticipated in the Karoo biome. According to Section 104 of the Constitution, it is possible for the Karoo to assign their own legislative powers to Municipal councils within their provinces (Constitution of the Republic of South Africa, 1996).

Regulation covering shale gas and hydraulic fracturing should exist at all levels of government, which includes the local, provincial and national government. This new proposed mining technique will have an impact on the Karoo community and the public of South Africa. The influence of political affiliation and business relations on broad regulatory exemptions must not create redundancy and confusion on shale gas, hydraulic fracturing, waste management or environmental protection. Roberts (2013) stated that the regulation should directly refer to shale gas and hydraulic fracturing. It can be attained through improving existing regulation or the development of new regulation specific to the management and development of shale gas and hydraulic fracturing.

2.5 CONCLUSION

This chapter has shown and addressed hydraulic fracking from a global perspective to a local perspective which is the Karoo in the South Africa. The chapter has reviewed literature available on hydraulic fracking and shows that there is a gap in the literature study especially with regards to the proposed fracking in the Karoo. On the global perspective, literature is mostly from USA

since it is a country which has been practising fracking for over 10 years. It has the largest shale deposit across the globe therefore the literature study has been directed to the USA.

Hydraulic fracking in South Africa is disputed by many organisations including the I&AP's. There is not much information or literature with regards to fracking in South Africa. Therefore people are not well informed about this proposed mining process. It is easy for them to dispute the whole process since South African government has not really shown transparency on the decision making while allowing hydraulic fracking explorations to proceed. Furthermore, the government has not shown its strength and capacity availability to conduct this mining process successfully. Most of the people can relate groundwater contamination to hydraulic fracking, but there is less literature study to prove if fracking will indeed contaminate the groundwater. The literature should identify the control and management measures used to ensure that the fracking process is monitored through certain regulations as preventions to any potential impacts.

CHAPTER THREE

METHODOLOGICAL CONSIDERATIONS

3.1 INTRODUCTION

This chapter would concentrate on the discussion of the methodological approach of the study. It will provide a detailed discussion of the various methodological approaches used in this investigation. Research methodology is a series of methods towards problem solving using codified series of steps to complete a certain task or to reach research objectives (Camarinha-Matos, 2012). In addition, a good methodology allows a researcher to put effort into cohesive and conceptual research idea to search for new and useful information on the research topic.

The methodological approaches which were used for this research are discussed in various sections of this chapter. The first section is 3.1 introduction then followed by 3.2 research philosophy this section analyses the type of philosophies that the researcher is associated with. It is then followed by section 3.3 research design which further elaborates on the designs that will be used to initiate the research methods. This section is further divided respectively into section 3.3.1 which is the description of the research study and section 3.3.2 dealing with study population and sampling procedure. An overview of data collection tools are discussed in section 3.4 which will include the details of interviews and historical approach used as tools for data collection. Once the data has been collected, it has to be scientifically analysed, this is covered in section 3.5. Section 3.6 gives an overview of the methodological reflections experienced by the researcher during the study. Last section 3.7 is the conclusion of the research methodology.

3.2 DESCRIPTION OF THE STUDY AREA

The Great Karoo covers approximately 400 000km^2 in the geographic midriff of South Africa stretching over the provinces of Eastern, Northern and Western Cape (The Great Karoo, 2014). According to Fox and Rowntree (2013) the Karoo lies on the south draining slopes of the great escarpment approximately on the southern coast line. It is a unique biome which is characterised as a pristine semi desert natural region forming a distinct geological division of the country (The

Great Karoo, 2014). It is one of the driest areas in the country and faces serious water shortage. According to The Great Karoo (2014) water availability in the Karoo is limited and ground water level is partially low. The rainfall ranges from 200mm/p.a. to over 1000mm/p.a. (National water resource strategy, 2014).

According to Vermeulen (2012) the geomorphology of the area is characterised as unspoiled landscapes, rich and special ecosystems with a variety of species endemic to the Karoo**.** Vermeulen (2012) indicates that the Karoo is also characterised with the presence of dolerites dykes and sills. Vermeulen (2012) further elaborates that the Karoo is the only known instance where shale gas targets have been intruded by dolerites. There is little known about the orientation of dolerite at depth greater than that typically reached by boreholes (Vermeulen, 2012). According to Vermeulen (2012) natural gas identified in the Karoo may have deposits as large as 485Tcf making it the fifth largest deposit in the world.

Van Tonder (2013) states that much interest of the South Africa's hydraulic fracturing is directed towards the Karoo because of its potential to deliver economically viable shale gas reserves and the potential future fuel source. Mentor (2012) further indicates that the current successful contributors of the Karoo economy have been through tourism, game farming and sheep farming being the dominant economic pursuit. Although fracking in the Karoo is pursued as the potential economic contributor, the great concern amongst residents and fellow South African citizens is the potential impact of hydraulic fracking on groundwater contamination (Mentor, 2012). According to Van Tonder (2013) most of the rural areas and some inland cities in the Karoo are dependent on groundwater for portable water supply. This is one of the key issues being debated on the protection of groundwater resources in the rural areas which also brings the interest of the research study.

3.3 RESEARCH PHILOSOPHY

Research philosophy is used to approach the study field while considering the epistemological position of the researcher. Raddon (2010) describes epistemological position as theory of knowledge and how the researcher views the world underpinning theoretical perspective and

methodology. Epistemological position can be personal and subjective views that influence how we conduct and interpret the research. Researchers might disagree about a piece of research because of the difference in epistemological understanding. It is therefore important for a researcher to state his/her position in order to lay a clear foundation for research study.

The research strategy adapted in this study is a constructivist method used to assess hydraulic fracking in the context of South Africa. By definition constructivist philosophy is of grounded theory which is an interpretive tradition, it is a concept that looks at understanding something in the context of social world (Andrew, 2012). The features of this philosophy will be used to understand the role of legislative measures to protect groundwater from contaminations during the fracking process. The researcher assumes that the issues of potential groundwater contamination caused by fracking and the regulations for water management are major concerns which is why it remain a subjective reality that needs to be investigated, discovered and constructed through interacting with the research participants.

3.4 RESEARCH DESIGN

3.4.1 Description of materials and data source

This research intended to explore the potential impacts of hydraulic fracturing in the Karoo on groundwater contamination and to assess the South African institute's capacities to manage water resources. Therefore to further explore this study in details the key focus was on hydraulic fracking in the Karoo which is based in South Africa. Research study can involve different techniques to collect data. On this study the survey method was used to gather empirical information in a form of a qualitative approach. According to Leedy and Ormrod (2001), qualitative approach enables respondents to expand on the question points without limit. The structure of the study was conducted by interacting with people or experts on the research topic, who are able to provide required information on hydraulic fracturing.

Quantitative design can be experimental subjects or to be sampled and therefore in experiments, bias is less likely to occur if subjects are randomly assigned (Leedy and Ormrod, 2001). The experiment included purposive and snowball sampling for data collection. Purposive sampling

focuses on the strategies and group participants according to preselected criteria relevant to a particular research question (Patton, 2002). Snowball sampling is a chain referral sampling where participants contacts are available to the researcher in social networks (Qualitative Research Methods: A Data Collectors Field Guide, 2005).

The data that informs the study was gathered from different mining expects with the focus of fracking in the Karoo. During the time of the research study there was no actual hydraulic fracturing process taking place in the Karoo, it was only the explorations being conducted. There was no data collected at the actual study site, therefore this research study was not geological positioned in the Karoo.

3.4.2 Study population and sampling procedure

The nature of the study required interaction with research participants who are knowledgeable or involved in the mining sector but with the focus on hydraulic fracking in the Karoo. A number of departments and key informants were gathered from different organizations including private and government institutes involved in mining sector in South Africa. According to Patton (2002), key informant is a person or group of people with unique skills or professional background related to the issue being evaluated. That person has access to other information of interest to the researcher. The key informants who were identified and selected for the research included: environmental departments, petroleum companies, academic organizations, energy and mineral departments, water departments, trade industry, geology and geophysics representatives.

Different participants identified as key informants were used to gather the empirical information in a form of a qualitative approach. Qualitative research is a scientific research which aims to seek answers to questions, collects evidence and produces findings that were not determined in advance (Qualitative Research Methods, 2005). Therefore, qualitative approach helped draw the individual's perception and experiences about the potential impacts of hydraulic fracturing on groundwater contamination and the institutional capabilities in water management.

The researcher decided to use a purposive random sampling technique as the study was looking for specific informants that have specific knowledge of the study research. This method helped

the researcher in ensuring that only informants with experience in mining particularly hydraulic fracking get an opportunity to participate in the study. Therefore, purposive sampling was facilitated by the snowball sampling technique. Some phenomenon's experienced by a group of people, it is therefore necessary to purposefully select individuals or group of people who meet the specific study criteria (Patton, 2002). Snowball sampling is known as a chain referral sampling. Selected research participants can make use of their social networks to refer the researcher to other people who could be of potential in the study (Qualitative Research Methods, 2005). Because the study was specialized, the researcher had to target certain people to participate in the study. Therefore a public relations representative was approached to help identify the key informants who are essential for the study. The public relations representative recommended speaking to expects in the identified organisations mentioned above.

From each of the identified organisations it was purposively decided to interview the following numbers of participants:

Table 3.1: Research study identified and interviewed key informants

Research study key informants	**Targeted population sample**	**Percentage %**
Geology and Geophysics	5	12.5
Petroleum Engineers	4	10
Energy and Mineral Department	10	25
Department of Water Affairs	9	22.5
Environmental Management bodies	8	20
Trade Industry	4	10
Total	40	100

Source: field materials

The total number of interviews required for the study was 40. Since the study focus on mining and particularly on hydraulic fracking, the researcher decided to include more participants from the Department of water affairs, Energy and Mineral Department and the environmental management representatives as the most important key informants for the research study. This is because the study was based on hydraulic fracturing mining process, the potential environmental

impacts on groundwater contamination and the institutional capabilities on water management. This is the reason more participants from those departments were selected to participate in the research interviews compared to other identified key informants. All the selected private and government departments are well known and have high number of employees working in the organization on different business units across the country. All the government departments operate throughout the whole country but the participants of the study were purposefully selected. The selected key informants were those who could bring up the most valid information with unique skills and professional background and could be reached for the research study. Informants were those affected or those having more interest in the study. These informants included both the organizations individuals with high power, medium power and low power within their organizations to ensure that all departmental ranks were covered in the study.

3.4 DATA COLLECTION TOOLS

a) Semi-structured interviews

Interviews are the most common methods used for data collection in a qualitative research (Gill et al., 2008). Gill et al., (2008) elaborates that interviews can be used to learn the views, experience, beliefs and motivations of individual participants. There are three types of research interviews; structured, semi-structured and unstructured interview. As for this study semi-structured interview questionnaire was selected as the main method for data collection. Cater (2013) defines semi-structured interviews as a semi-formal conversation between key informants and the researcher. Interview flexibility allows the researcher to probe deeper where more relevant information can be acquired through further interaction.

All the identified key informants were communicated with and invited through the use of a telephone or email to participate in the research study interviews. In the invitation each individual or organisation, was provided with the research study information which included the participant information sheet and the consent form. For all individuals who confirmed to participate in the study, the interview was then scheduled to suite their availability and convenience with regard to time and place. All research participants were given the same research questionnaire. There was one interview guide with open end questions designed for all

identified expects. The interview guide was divided into three sections. All the questions were open end which were meant to guide the participants into discussion. The open end questions left room for further explanation and elaboration by the participants. The questionnaire probe deeper and allowed for the discovery of how people feel or view hydraulic fracturing according to their own perspective. The first section of the questionnaire was meant to gain information on the fracking perception, participant's knowledge assessment of hydraulic fracturing, the potential benefits and challenges of fracking. The second section of the questionnaire focused on the fracking in the Karoo. The questions were directed to address the issues of water required for fracking and environmental impacts associated with hydraulic fracturing. The last section of the questionnaire required participants to give their views on South African institutional response to fracking. The questionnaire allowed participants to identify any known policies and regulations which govern fracking, the resources required for fracking and water supply protection in South Africa.

The face to face interviews were scheduled for nine participants who agreed to the face to face interviews and they were conducted at their respective offices. Only nine participants agreed to the face to face interviews, four of them were from the environmental department, three from the energy and mineral department and two from the water department. The face to face interviews session lasted for duration of about one hour with an individual participant. If there was more than one participant in the organization, the interview would be done separately to avoid recording the same answers. Telephonic interviews were also conducted with those participants who agreed to telephonic interview conduct. Telephonic interviews were conducted with 25 officials inclusive of all identified organisation in the research. A land line phone with a recorder was used during the interview; the participants were also notified that the conversations were being recorded. The telephonic interviews lasted for duration of 10 to 15 minutes long per person. Some of these telephonic interviews could not be finished in one phone call session; therefore time had to be arranged at a later stage to continue with the telephonic interviews. The interview questions were emailed to non-available participants for the face to face interviews. A total of six participants agreed to the email interview session of which two of the participants were geologists, two Petroleum representatives and two from the trade industry. The email interview participants took a week to a month to respond and to email back the interview

answers. During the waiting period the researcher called and sent follow up emails to the participants as a reminder to complete and send back the questionnaire.

Most of participants were too busy or simply not willing to speak out on hydraulic fracturing. They thought that the information provided could be used against them or their company. In some cases the participant kept on postponing the interview dates or they were not available for the set dates. As the interview sessions continued with the participants, the data recording was becoming repetitive. Marshall (1996) argues that an appropriate sample size in a qualitative research study is one that is large enough to allow the researcher to conclude effectively on the research question. Fusch and Ness (2015) described data saturation as a presence of enough information gathered resulting in the replication of the study. It is the ability to obtain additional new information when further coding is no longer feasible. Since the study saturation was reached at 40 interviews, the researcher concluded not to continue with interviews.

b) Literature review

For a study of this nature that looks at hydraulic fracking, it was also important to look at the secondary data of the study. Data review was used to address all facets of the research such as the "history" and "current" debates on fracking in South Africa. The research also examined the review of the institutional capabilities; these were reviewed through the studies of comparative literature surveys. The review of the secondary data was collected through textbooks, published works, periodicals, newspapers, popular articles, corporate reports, conference proceedings, journals and applicable legislation. Books were gathered from the library. Google and websites such as science direct were used to search for related hydraulic fracturing journals. The related themes which were searched on websites included mining history, hydraulic fracturing, environmental management, sustainability, the legal framework and the South African mandated institutes on the issue of fracking.

A detailed study on any existence of legal and institution framework was done on regulations correlated to hydraulic fracturing and water management in the Karoo. Different documents were found in South African regulations, such as Mineral and Petroleum Resources Development Act (Act no. 28 of 2002), National Environmental Management Act (Act no. 107 of 1998), national

Water Act (Act no 36 of 1998), Waste/ Waste Water Management and other relevant regulations and policies.

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Construct models of the flow in vertical direction and with horizontal flow and mass transport were reviewed to assess the hydraulic fracturing environmental impacts on the groundwater resources. The hydrology literature was used to investigate the probable spread of the pollution in water resources. The distance from the fresh water aquifer to the shale formation was analysed to assess the probabilities of groundwater getting contaminated. The hydrology literature of the Karoo was assessed from the available baseline data of Karoo gas exploration project. The hydrology literature of the Karoo consists of the Karoo groundwater atlas, Geological and hydrological maps also the national and groundwater archives and reports.

3.5 DATA ANALYSIS

Data analysis is determined by the type of data collected, during the process of designing the questionnaire it is important to consider how data will be captured and analysed. For this study a standardized semi structure interview questionnaire was used to interview all the identified research participants. The semi structured interview guide consisted of open ended questions. The semi-structured questionnaires were analysed to answer the research questions.

The collected data was mixed between written comments, statistical and information from open end questionnaire. The data was analysed using thematic content analysis. All the transcripts were read, highlighting the keywords, themes and ideas found within the scripts to determine patterns of repetition and information that was abstract to the research. Then the remaining required information on the scripts was then imported into Microsoft Excel spreadsheet, to first screen for erroneous data. The views that reoccurred frequently and the new ones were considered important for the findings and added in the discussion chapter for their significance to be discussed. On Microsoft Excel, questionnaires were coded and computed on preparing for statistical analysis. Descriptive coding was used to investigate the emerging and repeating contexts, practices, judgements and experiences in the data. The identified patterns were

therefore grouped into categories to further describe analyses and organize data. All descriptive coded data was then combined as well as other narratives from the interview questionnaires which would support the data analysis. Data quality was then analysed using the descriptive statistics.

3.6 METHODOLOGICAL REFLECTIONS

It is expected to experience challenges during the research study process. Chambers (1983) supports the view that a researcher is exposed to a number of biases during the phase of fieldwork. One of the encounters experienced from the study was feedback from the research participants. Most of the research participants who were invited via an email to participate in the research interviews never responded to the email. Despite the number of emails sent and calls made, it was difficult to get responses from the participants due to their unavailability. Therefore to manage this problem and avoid research data collection delays; the interview plan was changed to use telephonic interviews with most of the participants.

Another methodological challenge encountered was with regard to the structuring of the semi-structure interview questionnaires. The questionnaire consisted of 13 questions and it was only realized during the interview sessions that there were many questions. In addition, other participants were not knowledgeable of the research topic of hydraulic fracturing. This resulted in some questions remaining not fully answered. However this was controlled by rescheduling those interview sessions with the participant to be held when they had more time available. The questions were further broken down into simple terms during the interview sessions, for participants to understand them.

Another challenge encountered during the research study was time availability for data collection. Since the researcher is a full time employee, she had to divide the time between the research and work. This was a challenge. This resulted in some of the scheduled interview sessions being missed. However this was managed by emailing research questions to the participants and or rescheduling the research interview appointments. For those face to face interviews conducted with the participants were effective. The face to face interviews allowed a

better understanding and trust as an opportunity for the participants to provide more valued information.

The research data collection also contributed positively to the researcher, the researcher acquired different experiences and knowledge from different participants and various institutes during the research interviews. The interaction with the participants enriched and motivated the researcher on things such as research study, career opportunities and social being.

3.7 CONCLUSIONS

The methodological approach is simply a guide used to select the sampled population, collected data and analyses of the data. This study followed the qualitative research approach with the use of purposive and snowball sampling method to obtain the experienced required participants for the research. The use of semi-structured interview questions allowed the researcher to engage with the participants to collect quality data that will inform and answer the research questions.

CHAPTER FOUR

EMPERICAL EVIDENCE

4.1 INTRODUCTION

This chapter will elaborate the empirical findings of the research study. It outlines data collected from semi-structured interviews conducted with 40 participants from different organisations including government departments. It is then followed by the review of secondary data which includes the review of legislations and identifying gaps in legislations related to the proposed hydraulic fracking in the Karoo. The findings from the research interviews and secondary data are set out below. The results fall under the three research questions which were identified in chapter one.

4.2 POTENTIAL ENVIRONMENTAL IMPACTS OF HYDRAULIC FRACKING ON GROUNDWATER RESOURCES IN THE KAROO

This section presents the evidence of the overall question for this study. It presents the participants opinions, perception and knowledge on potential environmental impacts of hydraulic fracking on groundwater resources. Research participants give views on their knowledge of fracking, its challenges, and opinions on the amount of water required for hydraulic fracking operations. Other studies on groundwater contaminations due to hydraulic fracking operations revealed that fracking flow back disposal and the potential environmental impacts could emerge at the Karoo from hydraulic fracking processes.

4.2.1 Research participants interpretation and knowledge of hydraulic fracking process

Participants were asked questions and to express their knowledge of hydraulic fracking. The participants interpreted hydraulic fracking according to their own understanding but with the

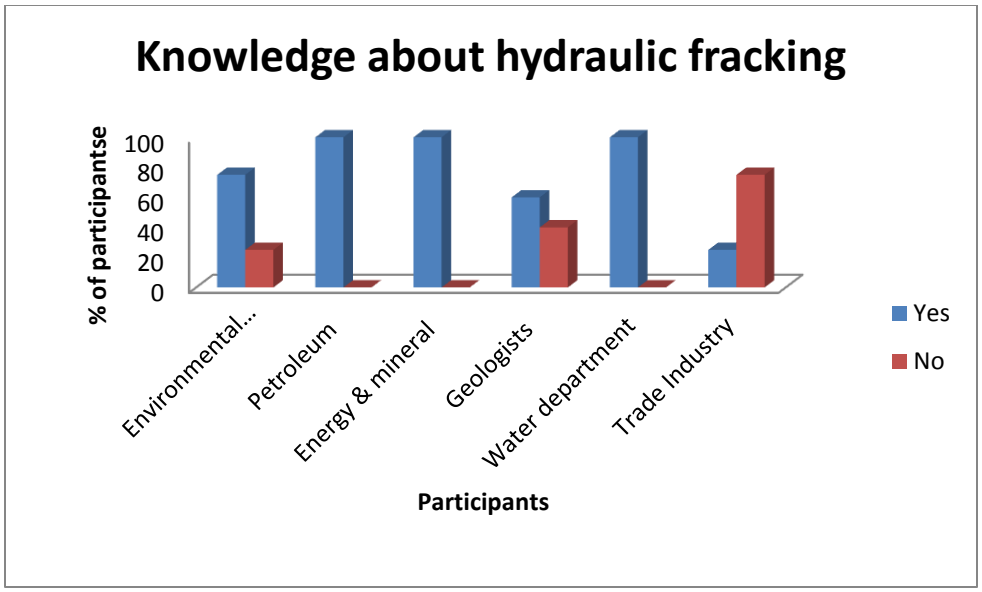
same concept. As indicated below in figure 4.1, participants from all departments interviewed had an understanding or knowledge on hydraulic fracking. All participants from the petroleum, energy & mineral and the water department had a better understanding of hydraulic fracking and what it entails. Most of the trade industry participants with an indication of 80% did not know about hydraulic fracking (figure 4.1.).

Table 4.1: Participants knowledge on hydraulic fracking.

Participants	**No. respondents**	**Yes** (participants know fracking)	**No** (participants do not know fracking)
Environmental activists	8	6	2
Petroleum representatives	4	4	0
Energy & Minerals	10	10	0
Geology & Geophysics	5	3	2
Water department	9	9	0
Trade industry	4	1	3
Total	**40**	**33**	**7**

Source: fieldwork based materials

Table 4.1 above indicates that 33 out of a total of 40 participants understood what hydraulic fracking was. All participants within the water department, petroleum and energy & mineral were knowledgeable about hydraulic fracking. One participant in a total of four from the trade industry knew about hydraulic fracking while the other three participants did not have a better understanding of fracking.



Source: Fieldwork materials based on table 4.1

Figure 4.1: Participants knowledge about hydraulic fracking

Figure 4.1 indicates that all departments interviewed had an understanding of hydraulic fracking. 100% of the petroleum, water department and the energy & mineral participants all knew and understood what is hydraulic fracking and what it entails.

Results showed that most of the individuals interviewed had more than one phrase to describe hydraulic fracking. The most common response of defining hydraulic fracking was inclusive of:

Table 4.2: Participant's key phrases to describe hydraulic fracking

Key phrases to describe hydraulic fracking
Producing oil and natural gas resources;
Release of tight gas from underground formation,
Creation of fractures from underground to allow gas to flow to the surface,
Cracking shale rock to release shale gas,
Digging of long well to release trapped shale gas,

Pumping large amount of water to release gas,
A technique used to mine shale gas,
Elaborating on the history of fracking and that the process was first used in the USA,

Source: fieldwork based materials

The response given by the participants gives evidence that the participants are aware that hydraulic fracking is a mining technique. It is a new technique used to release the shale gas from the trapped shale rock.

Most of the participants were abstract on giving the answers as they were more knowledgeable of hydraulic fracking from the background of their field. They even took further the definition of hydraulic fracking by elaborating on the history of hydraulic fracking. Some of the fracking history background given during the interviews includes; Pers. Comm (2015a) *fracking has been in operation for over 10 years in the USA and it was the first country to practise fracking. Furthermore, USA fracking has been successful. Yet there were also other lessons learnt from mistakes which resulted in environmental and social impacts (*Pers. Comm, 2015b*).* In this study, it was observed that each organisation understands fracking differently; the definitions given were more closely related to the participant's operation background or department. Participants from the energy department had more similar interpretation of fracking while those participants from the department of water affairs their explanations were relevant to their own department.

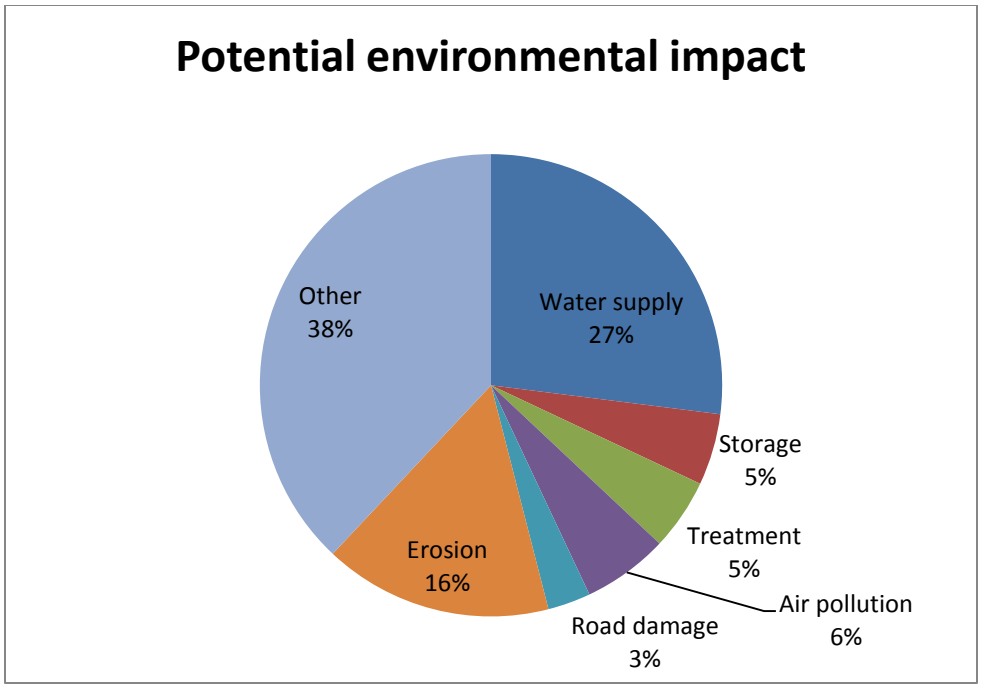
4.2.2 What are the environmental impacts associated with hydraulic fracking?

Table 4.3: Participants view on whether hydraulic fracking will cause environmental impacts in the Karoo.

Participants	**Yes** (fracking will cause environmental impacts)		**No** (fracking will not cause environmental impacts)		**Maybe** (Maybe fracking will cause environmental impacts)	
	No.	**%**	**No.**	**%**	**No.**	**%**
Environmental activists	6	75	2	25	0	0
Petroleum representatives	3	75	0	0	1	25
Energy & Minerals	5	50	4	40	1	10
Geology & Geophysics	4	80	1	10	0	0
Water department	9	100	0	0	0	0
Trade industry	3	75	1	25	0	0
Other	0	0	0	0	0	0
TOTAL	**30**	**65%**	**8**	**14.3%**	**2**	**5%**

Source: fieldwork based materials

Table 4.3, above indicates that 65% of the participants interviewed recon that hydraulic fracking operations in the Karoo will have some form of environmental impacts. Only 5% of the participants were of the view that hydraulic fracking might pose or not pose any environmental impacts. The energy & minerals department is the only department with 40% of participants that said there might not be environmental impacts caused by hydraulic fracking in the Karoo. (Pers. Com, 2015 c) from the energy and mineral department *explained that they have dealt with many operations of minerals mining. He further adds that usually the impacts or pollutions in the mining sector are only experienced if there is poor management or non-conformance to the regulations set for the mining operations.*



Source: fieldwork material based on table 4.3

Figure 4.2: Pie chart representing potential environmental impacts from hydraulic fracturing process

The pie chart above identifies the potential environmental impacts that could emerge at the Karoo from hydraulic fracturing process. A great number of participants indicated other impacts that could emerge as a result of fracking; these impacts were not available on the interview questionnaire. These "other" impacts are identified below in table 4.4. As identified in figure 4.2, participants noted that water supply will have high impact of 27% compared to other identified variables. In figure 4.2 participants stated that fracking process would have major impact on roads; this is indicated on the pie chart by a rating of 3% on road damage. The storage and treatment of water used for fracking both have a rating of 5%. Fracking process is believed to cause erosion impacts and 16% of the participants agreed to this.

Table 4.4: Potential environmental impacts that could emerge at the Karoo from hydraulic fracking

Participants	**"Other" environmental impacts**	**No.**	**%**
Environmentalists	Impact on protected species and habitats Protected habitats, national and geological protected sites Fynbos and vegetation impact Archaeology and heritage resources Contribute to climate change Demographic impacts Dust Noise Threat to human Floods	7	88%
Energy and mineral department	Archaeology and heritage resources Contribute to climate change Land stability Birds and wildlife Demographic impacts Land scape Dust	5	50%
Petroleum	Archaeology and heritage resources Land stability Land scape	3	75%
Water departments	Contribute to climate change Protected habitats, national and geological protected sites Birds and wildlife Threat to human	9	100%
Geology and	Protected habitats, national and geological	4	80%

geophysics	protected sites Archaeology and heritage resources Contribute to climate change Floods Land stability Demographic impacts Land scape Dust		
Trade industries	Demographic impacts Noise Threat to human	3	75%

Source: fieldwork based materials

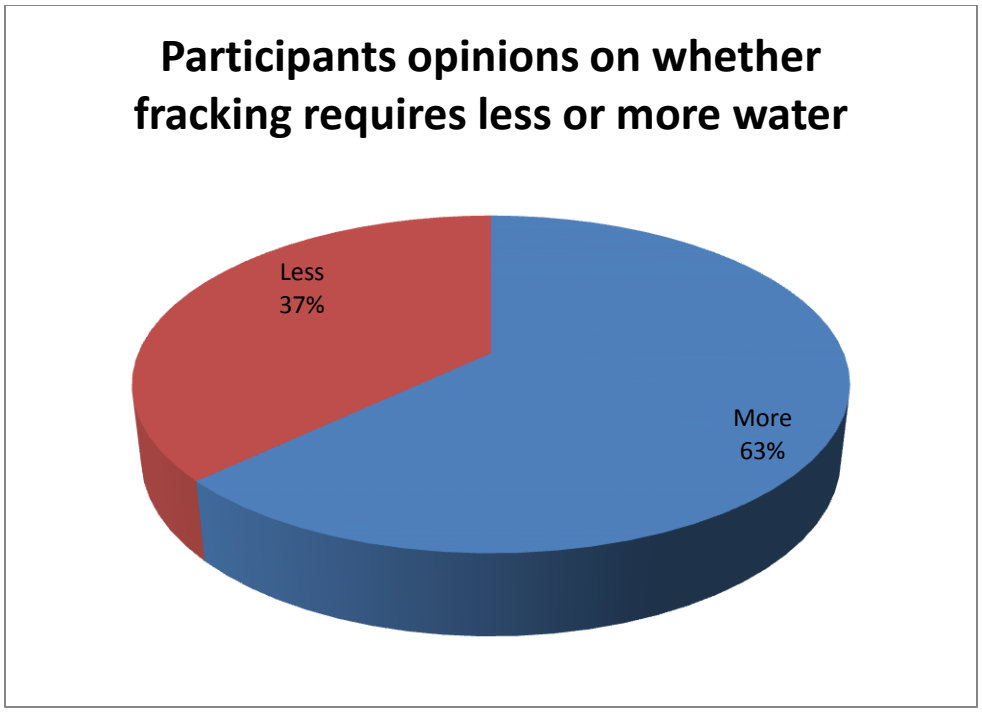
In the above table 4.4, within interviewed departments above 80% of participants indicated "other" potential environmental impacts which were not identified in the interview questionnaire. It is only the department of energy & mineral participants who indicated that "other" environmental impacts that could emerge will be low at 50%.

4.2.3 Participant's opinions on the amount of water required for hydraulic fracking operations.

Table 4.5: Participant's opinion on whether fracking requires less or more water

Participants	Yes (fracking requires more water)	No (fracking requires less water)
Environmental activists	8	0
Petroleum	1	3
Energy & mineral Depart	5	3
Geology & Geophysics reps	2	3
Water department	6	1
Trade Industry	0	3
Total	22	13
TOTAL%	63	37

Source: fieldwork based materials



Source: fieldwork materials based on table 4.5

Figure 4.3: Participants opinions on the amount of water required for hydraulic fracking operations.

Figure 4.3 indicated that 63% of the research participants agreed that hydraulic fracking operations will require more water; while only 37% stated that fracking will require less water. (Pers. Com, 2015 a & c) from the energy and mineral department *elaborated that the large amount of water is required in order to achieve fracking operation.* The explanation by the department of energy & mineral department was contextualised to their normal mining processes. The interpretation by participants from water department is that *fracking companies should be able to take responsibility and manage water use* (Pers. Com, 2015 d). According to Pers. Com (2015 e) *if there are any suggested ways to reuse the fracking water for another well, then they should implement the method for sustainable use. The permits for accessing water should clearly state the duration and capacity of water required for the fracking process* (Pers. Com, 2015 f). Healy (2012) indicated that the amount of water required for fracking processes is between 300 000 litres and 6 million. Participants from the water department were very much concerned about this large amount of water required for hydraulic fracking.

The trade industry participants placed emphasis on the future generations. A participant stated that "*I understand that the fracking process requires large amount of water but that cannot stop fracking to be permitted in the Karoo"* (Pers. Com, 2015 g). *He further elaborated that there would always be negative objectives regardless that fracking is a new mining technique in South Africa; surely even other existing mining techniques are still discriminated. Therefore the public has to look further into the economic growth of the country. It is important to have legislations which govern the fracking to sustain present and future generations* (Pers. Com, 2015 h).

By understanding the large amount of water required for fracking, the participants from the environmental bodies consider the environment and the needs of people. *Fracking requires lots of water and other sectors might be affected or have water shortage such as the agriculture sector* (Pers. Com, 2015 r). *There is no guarantee to possible water contamination. According to* Pers. Com, (2015 i) *South Africa is water scares country as a whole and the Karoo does not have enough water to support fracking. Water required for fracking raises concerns for water shortage as this required water is the highest amongst all industries* (Pers. Com, 2015 i).

According to the department of energy and mineral participant, *the amount of water required for fracking process varies from well to well depending on the structure of the well* (Pers. Com, 2015 c). *The amount of water required or used will rise as fracking expands. Since, the amount of water required for the fracking process is a lot; South Africa is a semi-arid country, the Karoo is a dry biome with no sufficient water, this water can be used for other activities (*Pers. Com, 2015 *a). If water required for fracking is obtained from the Karoo, this will result in water shortage for other uses in the Karoo (*Pers. Com, 2015 *p). Sustainable use should be practised with all natural resources and this includes water required for fracking in the Karoo* (Pers. Com, 2015 b). (Pers. Com, 2015 b) further adds that *the Karoo is depended on groundwater for households and farming, the amount of water required for fracking cannot be enough. Another participant opinion was that the amount of water required for fracking is exaggerated, there are other industries including mining and agriculture which also takes up a lot of water* (Pers. Com, 2015 a).

Petroleum participants noted that *the public perception and reaction on that fracking requires large amount of water but it is not the fact* (Pers. Com, 2015 j). *More water is used only from*

increased fracking production. Fracking would require more or less the same amount of water required in energy or mineral related production (Pers. Com, 2015 k).

The geologists indicated that *the amount of water required for fracking would be on a similar average as that required for producing oil* (Pers. Com, 2015 l). *In addition, the amount of water required for fracking depends on the underground geology and hydrocarbons. Water required for each well depends on the geological formation, therefore the amount of water will vary per well.* Pers. Com, (2015 m) opinion was that *it is a fact that fracking uses a lot of water. Water required for fracking cannot be associated as a problem because the very same water can be used for other wells. The amount of water required per well will depend on the rock formation* (Pers. Com, 2015 n). Another opinion of a geologist was that *water required for fracking is less compared to that of coal processing* (Pers. Com, 2015 o).

4.2.4 Lessons which can be learned from other studies in terms of groundwater contamination from fracking operations.

Participants from all departments interviewed identified different lessons of protecting groundwater from fracking process. Most of the identified lessons were related to fracking operations in the USA. Well USA is one of the countries that have been conducting successful hydraulic fracking operations for the longest time. This is a reason to why most participants referred to the USA fracking. Below is Table 4.6 indicating some of the hydraulic fracking lessons learnt from other countries already practising fracking. These lessons learnt were identified by the participants. Table 4.6 showed that the petroleum and energy & mineral participants identified more closely related lessons to the mining operations with environmental impacts. The water department participants stressed more water related issues and policies to protect the water resources.

Table 4.6 Hydraulic fracking lessons learnt identified by participants emerging from other countries already conducting fracking.

Participants	**Lessons learnt**
Environmental activists	- Contamination of water will remain the downfall of the Karoo. - Some of the examples from the USA show negative effects on animals and vegetation. - Even in the USA over 10 years of fracking, they cannot keep record of groundwater contamination; so how will they do it in South Africa. - It's possible that some of the records at the drilling well were not recorded; therefore it is possible that some of the groundwater contaminations are not known.
Petroleum representatives	- The gas companies have track records from other sites and these can be used to reduce associated fracking risks in the Karoo. - The previous experience can be used to determine what's needed in the future to protect groundwater.
Energy & Minerals	- USA has helped other countries to bring balance between energy security and environmental concerns. - USA has existing hydraulic fracking regulations to ensure that fracking is done safely and efficiently.
Geology & Geophysics	- Fracking pose danger of potential contamination of ancient reservoirs of under groundwater.
Water department	- USA government involved the environmental protection to study the relationship between fracking and drinking water. - Fracking is known to be conducted mostly in the USA and what can be learned are their continuous studies and researches to improve fracking policies and geological

	perspectives.
Trade industry	- USA has helped other countries by transferring expertise and teaching them about fracking.

Source: fieldwork based materials

4.3 IMPLICATIONS OF THE FINDINGS OF THIS STUDY IN A WIDER CONTEXT, PARTICULARLY IN SUB-SAHARAN AFRICA

Fracking being a new mining technique, it might be beneficial for the economic growth of South Africa. But beforehand, the government must have the required capacity to conduct successful hydraulic fracking. The research participants were given an opportunity to discuss and give their views concerning the state or local government involvement with the public interaction with regard to the proposed hydraulic fracking in the Karoo.

4.3.1 Significant public reaction with regards to fracking

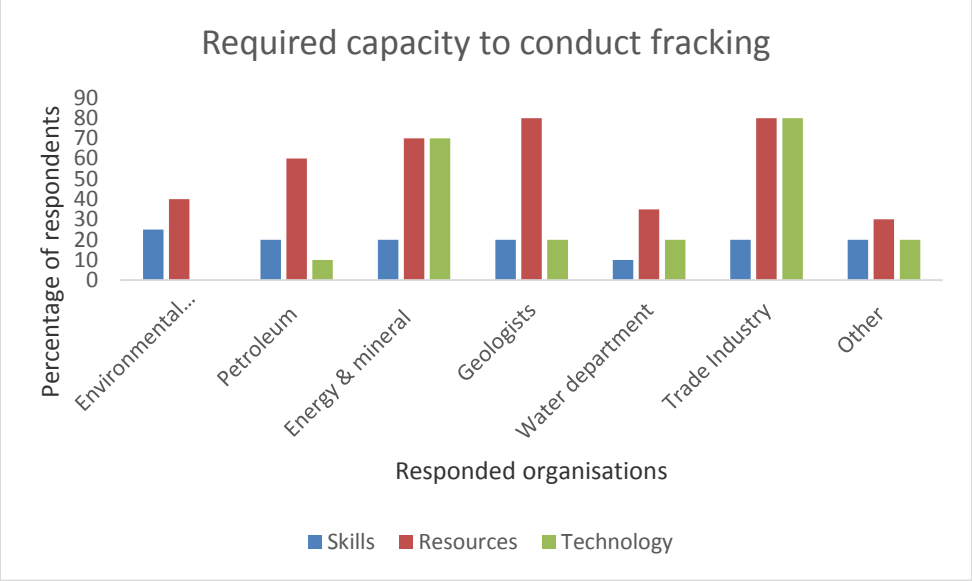
Pers. Com, (2015 a) *from the department of energy & mineral is of the view that one of the public concerns is that the public were relied on environmentalists to identify and report the foreseen environmental impacts from fracking but so far people are not certain about the possible impacts that could emerge from fracking operations. An environmental participant* Pers. Com (2015 i) *stated that the anti-fracking activists have called a global alliance against fracking. The biggest fear of the fracking activists groups and the public in the Karoo is the scarcity of water and groundwater contamination. A participant from the energy & mineral department said that the public claims that the mining companies always come with empty promises* (Pers. Com, 2015 b). *The treasure Karoo action group challenged shale gas developments voicing their fear on environment and health implications.* An environmentalist participant stated that *the public have concerns that most people will be disappointed about the promised empty benefits* (Pers. Com, 2015 i). *Poverty and lack of jobs will result in people supporting fracking just to provide for their families. A geologist stated complains of people on the corruption in South Africa* (Pers. Com, 2015 n). *The ruling party ANC is keen about fracking*

in the Karoo while neglecting the concern of the local people. Participant from the trade industry noted that *the local residences of the Karoo have raised concerns on the contamination of groundwater* (Pers. Com, 2015 h). *The government had to establish a moratorium on shale gas to allow time to study impacts of fracking.*

Table 4.7: Required capacity for South African government to conduct fracking.

Participants	Skills	Resources	Technology
Environmental activists	5	8	0
Petroleum	2	6	1
Energy & mineral	4	14	14
Geologists	2	8	2
Water department	2	7	4
Trade Industry	1	5	4
Other	2	3	2

Source: fieldwork based materials



Source: fieldwork materials based on table 4.7

Figure 4.4: the required capacity for the South African government to conduct fracking

During the interviews, participants from identified departments were asked to give their views on the capacity of the government to conduct hydraulic fracking in the Karoo. The graph above

(figure 4.4) showed that interviewed participants from different departments believed that resources are the most required capacity by the government. Trade industry and the department of energy & mineral participants identified resources and technology as the most essential capacity for fracking. The environmental bodies' participants viewed skills as the important required capacity for fracking process.

4.3.2 Participants views on the possible hydraulic fracking challenges

Table 4.8: Participants view on whether hydraulic fracking will pose challenges

Participants	**Yes %**	**No%**	**Respondents**
Environmental activists	8	0	8
Petroleum representatives	3	1	4
Energy & Minerals	7	3	10
Geology & Geophysics	4	1	5
Water department	6	3	9
Trade industry	2	2	4
TOTAL	**30**	**10**	**40**
TOTAL %	**75**	**25**	**100**

Source: field material

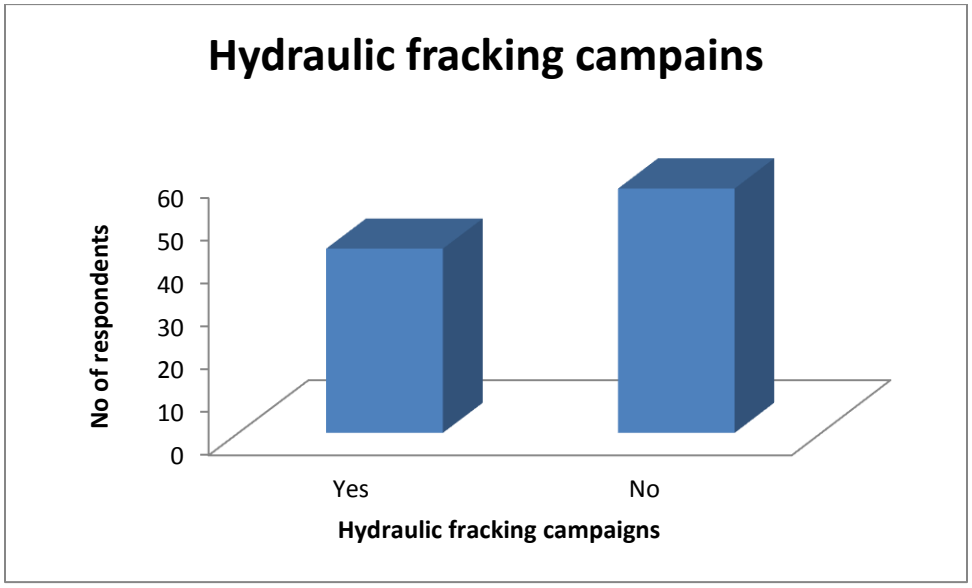
In table 4.8, 75% of the participants agreed that hydraulic fracking will pose challenges in South Africa. Most of those participants reported that; since fracking is a new technique; the first operations will be challenging to the government and the fracking companies.

4.3.3 The state or local government to address the public about fracking development

Table 4.9: Participants view on if the government is doing enough to keep the public informed about hydraulic fracking.

Participants	Respondents	Yes %	No%
Environmental activists	8	1	7
Petroleum representatives	4	3	1
Energy & Minerals	10	4	6
Geology & Geophysics	5	5	0
Water department	9	2	7
Trade industry	4	2	2
Other	0	0	0
TOTAL	**40**	**17**	**23**
TOTAL %	**100**	**43**	**57**

Source: fieldwork based materials



Source: fieldwork material based on table 4.9

Figure 4.5: Participants responds to fracking campaigns

Participants were asked if the state or local government does have any campaigns and public participations to inform the public about fracking development. The graph above (figure 4.5) indicated that 57% of participants disagreed with the fact that the government were not informing or giving updates on the progress of the fracking process. 43% of the participants agreed that there were hydraulic fracking campaigns being conducted. Many participants from the department of energy & minerals agreed that there were fracking campaigns; with the evident that department of energy & minerals released a fracking notice in 2013. (Pers. Com, 2015 a*) claims that the government has notified people about fracking in the Karoo that is why people do know that fracking has potential of groundwater contamination. Another participant* (Pers. Com, 2015 p*) from the* energy & minerals department *disagreed to this statement saying that there has been very little interaction with the local people by the government*.

Participants from the environmental bodies were of the opinion that there were no campaigns organised by the government to inform people about fracking in the Karoo. Pers. Com (2015 i*) is of the opinion that because of this, the treasure Karoo action group was started to raise awareness of the issues of shale gas. The anti-fracking groups were formed to demand answers and information from the government. A participant from the water department was of the view that the government was very active and informative while fracking was still being proposed and currently there is no communication (*Pers. Com, 2015 s). *He further explained that there has been lack of proper research and public consultation. Most people including the I&AP's were not informed about the exploration permit granted. There is no transparency from the government. The government and gas companies always have short notice for public participation. The public is not involved.*

Table 4.10: Potential benefits of fracking for the South African economic developments

Departments	Potential benefits	No of respondents	Percentage
Water affairs	- If fracking is to be permitted in SA, then the country will be energy independent. - For energy production, shale gas will reduce carbon emissions. - Foreign workforce will bring opportunities for economic growth. - Job creation - Bring more investors in the country - Reduce imported fuels - Reduced electricity tariffs - Karoo is a small town; fracking will result in boomtown caused by inflections of people into the town. - Specialists from outside the country will benefit not the local Karoo community. - Fracking will not bring benefits in anyhow; there are now more options on clean energy solutions such as solar energy. - Fracking will cause far more trouble and negative impacts than its worth. - There will be no large job creation than expected.	5	63%
Environmental bodies	- Fracking will not produce high economic benefits as there is no adequate infrastructure in SA - Inflow of people in Karoo for new opportunities and resources will be	2	25%

	diminished - Fracking will reduce carbon footprint generated from coal based energy production. - No expected benefits, the beautiful natural Karoo which attracted tourist might be destroyed. - It is not entirely certain that all the South African people might reap rich rewards especially the Karoo community. - Fracking is expensive and the utilising of land could contribute environmental impacts and concerns from people around the area. - Fracking will only bring negative impacts to the environment and people		
Energy & minerals	- Hydraulic fracking will solve energy problems in SA - SA will be able to produce its own gas which is good for economic growth. - SA might not benefit economically as they do not have skilled people, therefore most of the workforce will be foreign. - Fracking will be new mining techniques for the country; it will contribute positively to economic growth. - The government will therefore train more people and buy fracking facilities, in the long run this will contribute to economic growth - SA is in a better chance to conduct	6	60%

	fracking without impacts and delays as there are already lessons learnt from other countries particularly USA - Potential commercial benefits - More energy source for electricity production - Reduced electricity tariffs - New commercial market to the country's economy - Fracking will be a game charger for the gas market of South Africa and the whole continent		
Petroleum	- Increased job creation - Benefits of economy and mining technology of the country - New energy capacity - The economic benefits will be temporal because when fracking well is completed it is then closed down - Hydro fuel imports will drop	3	75%
Geology	- Reduce of coal-based electricity which could result in lower electricity tariffs. - Fracking will be a solution to energy problems in SA and electricity prices might go down as there will be other source of electricity supply. - There are many activities and developments for fracking process- these will create more job opportunities - It will help minimise greenhouse emissions - There will be more resources available for	3	60%

	energy supply - Fracking will help reduce poverty that exist in the area - Increase in potential economic benefits - Job creation for local people - Fracking will be an alternative to the country's reliance on coal for energy supply.		
Trade industry	- Job creation - New commercial trade in SA - Opportunities for the Trade Industry to conduct business with other countries interested in fracking or shale gas exports. - Fracking will be another mining technique to add up to the country's minerals and economy.	3	75%
TOTAL			**60%**

Source: fieldwork based materials

Table 4.10 showed that only 25% of the environmentalist agreed on hydraulic fracking potential economic benefits. Eighty percent (75%) of the environmental bodies stressed that fracking will only bring negative impacts onto the environment and people. They further said that fracking is an expensive mining technique and costly in case of an incident occurrence. In table 4.10 participants stated that the benefit of hydraulic fracking is in the creation of jobs, decreasing in electric tariffs and economic of South Africa. These departments have stressed several negative impacts on the economic development including; foreign countries benefiting rather than South Africa, no facilities or skills to conduct successful fracking. They have also identified potential benefits for the economic development of South Africa if fracking is to be permitted. 75% of the trade industry participants believe that hydraulic fracking is a new opportunity for the economic growth of South Africa.

4.4 REVIEW OF POLICY AND LEGISLATION FRAMEWORK

4.4.1 Mineral and Petroleum Resources Development Act, (Act No. 28 of 2002)

The MPRDA regulates any form of mineral mining in South Africa. Therefore any exploration of shale gas in South Africa including that of the proposed Karoo will fall within the minerals and petroleum resources development act of 2002 MPRDA. Fracking technique entails extraction of shale gas, it therefore falls within petroleum. Therefore it will be regulated by petroleum Agency SA. Petroleum Agency SA is responsible for the onshore and offshore oil and gas resources, their developments and production activities. This research has shown that hydraulic fracking it's a new proposed mining technique in South Africa, there were gaps identified in the MPRDA Act 2002, which needed to be amended in relation to hydraulic fracking in the Karoo. In addition, in 2013 the minister of Mineral and Petroleum identified gaps in the current regulatory framework of the petroleum resources exploration and exploitation Resources Development. These gaps identified in the regulation that needed to be addressed particularly for hydraulic fracking, included the safe exploration, production of petroleum, prescribed good international petroleum industry practices and standards (Mineral and Petroleum Resources Development Act 2002 No. 28 of 2002 notice 1032 of 2013).

In addition to regulation of managing and monitoring fracking, the MPRDA requires applicants to submit environmental management plans for management of impacts even at exploration stage. The plan identifies the possible risks and the mitigation measures that will be applied; this plan must be approved prior to the award of any right. The potential major potential impact of fracking is groundwater contamination. The possible risks, groundwater management and mitigation measures need to be identified as per section 39 (3) (d) of the MPRDA with the support of National Environmental Management. It is stipulated that Waste Act 2009 requires a contingency plan of how the migration of pollutants will be contained and managed. All stipulations mentioned in section 39 (3) must be adhered to before developing suitable control measures for pollution. In addition, the baseline environmental information, the completion of environmental impact assessment procedures and the description of risks must be included in the plan as contemplated in MPRDA Sections 39 (3) (a) (b) & (c). The environmental requirements' and implementation of the authorised environmental management plan are subjected to the

national framework environmental legislation and the National Environmental Management Act108 (1998) principles (Washington-fracking an alternative to alternatives, 2013)

4.4.2 National Water Act, (Act No. 36 of 1998)

According to section 22(1) of the National Water Act 36, 1998, all 'water use' are subjected to a license requirement which state certain authorisation of specified 'water use in section 39. South Africa faces a water crisis, on both quantity and quality of its water resources. The South Africa Environment Outlook (2005) stated that water quality is variable, with an overall deterioration since the 1999. In addition "Villiers and De Wit (2010) predicted water shortages of 19 to 33% for the country as a whole by 2025". In relation to the semi-arid Karoo, the most controversial aspect of hydraulic fracturing process has to do with the scarce water resources (Golder Associates, 2011). Fracking requires an amount of water of between 300 000 litres and 6 million litres per borehole. Outlining the statement above, water management for the fracking process needs to be monitored and have adhered guidelines permitting water use licence.

The Department of Water Affairs needs to ensure that the National Water Act 36(1998) for water use and licensing of water for the hydraulic fracking technique is managed. The major water issues to deal with at the Karoo are; partial water resources and the needs to be distributed equitably. There is more to do in the Karoo with regards to the supply of the amount of water required for fracking. This is justified by the lower levels of water available in the Karoo to support the fracking technique. Sourcing the vast volumes of water required for an extended fracking programme can be challenging, especially in arid area like the Karoo itself. This can result in extraction of water from small catchments which could have an impact on the ecology and hydrology of rivers in these areas. Note, these effects on water sources may not be apparent in the immediate short term, but may only be evident at the later stage.

According to Healy (2013) in section 21 of the National Water Act, (Act No. 36 of 1998) 'water use' includes:

(a) Taking water from a water resource;

(b) Storing water;
(c) Impeding or diverting the flow of water in a watercourse;
(d) Engaging in a stream flow reduction activity contemplated in section 36;
(e) Engaging in a controlled activity identified as such in section 37(1) or declared under section 38(1);
(f) Discharging waste or water containing waste into a water resource through a pipe, canal, sewer, sea outfall or other conduit;
(g) Disposing of waste in a manner which may detrimentally impact on a water resource;
(h) Disposing in any manner of water which contains waste from, or which has been heated in, any industrial or power generation process;
(i) Altering the bed, banks, course or characteristics of a watercourse;
(j) Removing, discharging or disposing of water found underground if it is necessary for the efficient continuation of an activity or for the safety of people; and,
(k) Using water for recreational purposes.

Definition of 'water-use' can be related to the hydraulic fracking activities. Some of the points identified above define "water use" as, (a) "taking water from water sources". Fracking requires an amount of water of between 300 000 litres and 6 million litres per borehole. This amount of water needs to be taken from certain water resources and it is known that the Karoo is an arid area. More water than the amount of 6 million litres per borehole can be required according to the volumes of water pumped into the drilled borehole during the fracking process. This does not guarantee the type of fractures created since the amount of water required depends on the geology of the well. "Healy (2013) stated that the array of fracture depends on the *in situ* stress, physical properties of the local rock volume, any pre-existing fractures and the pore fluid pressure". Therefore, there are implications on undergroundwater contamination as the fracture network details in the borehole could not be complex and unknown (Healy, 2013).

According to Healy (2013) fracking of extraction of shale gas basically involves the injection of fluids into the borehole well. The well is drilled vertically to the ground between 2000m to 5000m then extended horizontally up. The potential contamination of groundwater results from a leakage of chemicals used during the fracking process inside the boreholes or the seepage of

chemically wastewater from the surface (Healy, 2013). This shows that the "water use" activities of fracking can impact on the hydrological cycle. The hydraulic fracking process is an integrated approach which requires a decision-making process with a number of government departments representing different laws covering all gaps. The Department of Water Affairs is responsible for the issuing a water licence, or a general authorisation. According to section 27 of The National Water Act, 36 of 1998, in the event of issuing a general authorisation or licence, a responsible authority must take into account all relevant factors below (Healy, 2013)

(a) Existing lawful water uses;
(b) The need to redress the results of past racial and gender discrimination;
(c) Efficient and beneficial use of water in the public interest;
(d) The socio-economic impact-
    (i) of the water use or uses if authorised; or
    (ii) of the failure to authorise the water use or uses;
(e) Any catchment management strategy applicable to the relevant water resource;
(f) The likely effect of the water use to be authorised on the water resource and on other water users;
(g) The class and the resource quality objectives of the water resource;
(h) Investments already made and to be made by the water user in respect of the water use in question;
(i) The strategic importance of the water use to be authorised;
(j) The quality of water in the water resource which may be required for the reserve and for meeting international obligations; and
(k) The probable duration of any undertaking for which a water use is to be authorised.

Section 28 of the act identifies important conditions of licences. In addition to the issuing of licences or general authorisation, section 29 stipulates that the responsible authority may attach conditions to every licence. This is ideal for the fracking process; it is a new mining technique in South Africa and already poses high potential impact of groundwater contamination. The amount of water required for the fracking process is excessive and it is within an arid Karoo. Thereof the license must be bounded to certain conditions to ensure proper water use management. Section

29(2) says in case "a licensee has agreed to pay compensation to another person; in terms of any arrangement to use water, the responsible authority may make the obligation to pay compensation a condition of the licence".

4.4.3 National Environmental Management Act, (Act No. 107 of 1998)

The NEMA serves as guidelines to referred organisations when taking any decision or any statutory provision related to the protection and management of the environment. In addition, NEMA guides the interpretation, administration and implementation of environmental management. Furthermore, environmental obligations are imposed through a suite of national, provincial and local environmental legislation. This regulates impacts on air, biodiversity, water, coastal areas and impacts resulting from the disposal of waste.

In Chapter 5 of the NEMA, general objectives of Integrated Environmental Management are set out. Section 23(2)(f) requires that the identification and the modes of environmental management, for any particular activity, must be pursued in accordance with the principles of environmental management. Impacts of Hydraulic fracking on the environment include socioeconomic impacts and water resources. This calls to a full assessment of this mining technique beforehand. Some of the tools for further environmental assessment include the environmental impact assessment (EIA) and the strategic environmental assessment (SEA). This should be used to enable a evaluation against policies, land use and the regional development objectives and capability.

The National Environmental Management Act, (Act No. 107 of 1998) commence by stating that:

(a) Environmental management must place people and their needs at the forefront of its concern, and serve their physical, psychological, developmental, cultural and social interests equitably.

(b) Development must be socially, environmentally and economically sustainable.

(c) 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.

(d) The social, economic and environmental impacts of activities must be considered, assessed and evaluated; decisions must be appropriate in the light of such consideration and assessment.

4.4.4 Constitution of Republic of South Africa, 1996

The constitution of South Africa represents and protects the rights of the public. There are fundamental rights in the Constitution. These rights are the rights to wellbeing, to healthy environment, to sufficient food and water, to correct administrative action and the right to be information. Communities in the Karoo and generally across the country have the right to access transparent information with regards to hydraulic fracking negotiations and processes involved. Section 32 of the Constitution, state that people have the right to access information. It is argued that the rights to information includes the rights of the interested and affected parties; in terms of disclosure they have the right to comment at every step of the decision making process.

All these rights are applicable to the protection of public of the proposed hydraulic fracking in the Karoo. Fracking has the potential impact on the environment, groundwater, drinking water contamination and extraction of water resources. The right to sufficient water is stated in section 27(1) (b) of the Constitution. National Water Act (36, 1998) emphasise that a water licence should be declined on the ground of the rights to access to sufficient water among other things the Water Act lays down stringent water licensing criteria as well as providing for a 'Reserve. The environmental right section 24(b) (iii) of the Constitution secure ecologically sustainable development and the responsible use of natural resources while promoting economic and social development.

Section 24 of the Constitution states: Everyone has the right:

(a) To an environment that is not harmful to their health or well-being; and

(b) To have the environment protected, for the benefit of present and future generations, through reasonable legislative and other measures that

(i) Prevent pollution and ecological degradation;

(ii) Promote conservation; and

(c)Secure ecologically sustainable development and use of natural resources while promoting justifiable economic and social development.

4.4.5 Legislation and policy approach

Fracking and the exploitation of shale gas have been proposed as a new mining technique in the Karoo region of South Africa. This technique is unprecedented. The government might not have specific policy on such mining activity. Furthermore, fracking technique might pose serious implications on the environment and socioeconomic of the country, it therefore needs to be well regulated. Some of the institutional frameworks that exist in South Africa and manage fracking operations include; the water and environmental affairs, mineral resources and the petroleum agency. These departments are mandated to regulate hydraulic fracking operations, but it is important to assess other relevant institutes that can regulate the hydraulic fracking operations.

Table 4.11: Mandated regulations to govern hydraulic fracking

Departments	**MPRDA of 2002**		**NEMA of 1998**		**Water act of 1998**		**Constitution of SA**	
	#	**%**	**#**	**%**	**#**	**%**	**#**	**%**
Environmentalists	8	100%	8	100%	8	100%	8	100%
Petroleum	4	100%	4	100%	4	100%	3	75%
Energy & minerals	10	100%	10	100%	10	100%	10	100%
Geologists	5	100%	4	80%	5	100%	3	60%
Trade industry	4	100%	3	75%	3	75%	1	25%
TOTAL	**40**	**100%**	**38**	**91%**	**39**	**95%**	**33**	**72%**

Source: fieldwork based materials

In table 4.11 above, the environmentalists and other participants from the energy & mineral department suggested that hydraulic fracking should be regulated by all of the above mentioned regulations. This information was based on the South African Acts and the Constitutions on the

above table 4.11. Only 25% of the trade industry participants felt that the South African constitution can be used on hydraulic fracking. All research participants agreed that the MPRDA is responsible for fracking. Other identified regulations which the participants thought are applicable for hydraulic fracking includes the; waste/waste water management and the Strategic Environmental Assessment (SEA) for hydraulic fracking in the Karoo. These regulations can be used in an integrated and cooperative manner. It is important to record the institutional framework engagement to organise, to provide protection on water sources and if the government has the required resources to conduct fracking. Therefore before fracking process can be permitted in South Africa, critical reviews and development of regulations and policies must be decided by the government cabinet. In the development of regulation and polices, the proponent is required by various laws to undertake a number of studies before obtaining planning and authorisations.

These discussions were held with participants of different organisations. A participant from the department of water affairs (Pers. Comm, 2015p) suggested that *more studies on groundwater models and environmental mitigation measures should be included in the legal action. The South African water research commission should join together with other water study bodies in conducting research on water sources in the Karoo.* Another participant from the department of water affairs (Pers. Comm, 2015 r) stated that *water regulation needs to be amended to provide protection on water supply for fracking process.* A participant from one of the environmental bodies (Pers. Comm, 2015 i) stated that *South Africa is new in the gas industry; they lack infrastructure experience and regulation to apply to the industry. Therefore these are the things that need to be considered in the institutional framework. The regulatory body should be essential to hold the system of compliance. Strong policies should be in place to avoid corruption.* Another environmental participant (Pers. Comm, 2015s) noted that *even if laws can be made available, it is a different thing to abide to the law. He further added that the institute does not have the capabilities to maintain and put all checks according to the law. The participant was of the view that South Africa should train researchers and engineers to equip them with knowledge and facilities required for successful fracking. South African government should involve more academic researchers to conduct groundwater studies in the Karoo and the potential groundwater contamination* (Pers. Comm, 2015s).

(Pers. Comm, 2015 l) geologist participant mentioned that during the project phase, *continuous identification and mitigation compliance must be followed throughout the process and they must be detailed in the fracking regulations.* (Pers. Comm, 2015 j) petroleum participant states that *a monitoring committee should be made available to ensure continuous compliance of groundwater protection during fracking.* Trade industry said that "*although all institutional frameworks protect groundwater contamination, this should not prohibit or restrict fracking process as it is essential for the development of the economy.* According to Pers. Comm (2015c) a participant from the department of energy and mineral, *a set of appropriate regulations should be developed for fracking in the Karoo rather than adapting the whole regulations from successful fracking countries such as the USA. The institutional framework should include perspectives such as geology, water laws, heritage resources, waste management, environmental studies, fracking techniques, policies and the economic development*. *The state should implement production rights in terms of the mineral and petroleum resources development.* Another participant Pers. Comm (2015 f) noted that *fracking has become a public and regulatory issue rather than focusing more on the research studies*.

4.5 Conclusion

The study findings confirmed that the interviewed participants understood what fracking entails based on their operational background knowledge and the information on the proposed hydraulic fracking the Karoo. Participants identified the economic benefits and the challenges that the proposed hydraulic fracking face in the Karoo. Participants pointed out that groundwater contamination and the provision of capacity of resources and skills is the major impacts that will hold up fracking in the Karoo. Participants indicated that South Africa is concerned about fracking. This is justified by the fact that fracking is a new mining technique and the lack of transparency or and information about the processes from the government. Another concern outlined by the participants is that there is no fixed polices and legislations developed for the fracking process and the protection of groundwater from fracking contamination.

CHAPTER FIVE

ANALYSIS AND DISCUSSION

5.1 INTRODUCTION

This chapter will discuss the findings in the context of this research. It will analyse interview results and secondary data. The aim of this research was to investigate the South African current institutional set up in relation to environmental challenges associated with fracking. The study was particularly interested in investigating the relationship between institutional capabilities in the context of groundwater management. The analysis and interpretation of the research findings are discussed below in much more details. This discussion is structured to answer the research questions mentioned in chapter one which will be informed by the literature. During the discussions some of the issues will be referred to the findings in chapter 4.

5.2 POTENTIAL ENVIRONMENTAL IMPACTS OF HYDRAULIC FRACKING ON GROUNDWATER RESOURCES IN THE CONTEXT OF SOUTH AFRICA

Findings of the research have indicated that hydraulic fracking pose potential environmental impacts on groundwater contamination. It has been evident that the biggest concern that people have is the contamination of groundwater from the fracking process. These impacts are either generated through the preparations of hydraulic fracking or during the fracking process and possibly also at the close out of the fracking hole. In addition, the analysis of the data indicated that the expected groundwater contamination is from failure of drilling and possible leaks of fracking fluids during the fracking process.

The findings indicate that even other mining techniques have been contributing to the environmental impacts; it will not only be hydraulic fracking impacting on the environment. In the literature it was identified that it has been evident that during any mining process, there is always some form of environmental disturbance occurring either during the preparation of mining process or during the actual mining process. In relation to groundwater contamination, the contributing factor to the research finding is that even in other mineral mining operations,

groundwater contamination has always been the biggest challenge in the mining sector. Tanner et al., (1999) are of the view that mining in South Africa highly contributes to wastewater that have the potential to adversely affect water resource due to poor managed. Now, with hydraulic fracking which is known to cause methane leaks which is not visible by a naked eye, groundwater contamination remains the biggest environmental impact challenge.

Mine water treatment is a possible solution to prevent or minimize the pollution of water resources. However it has been regarded in the literature as a very expensive process to treat the water to a condition acceptable for release into natural watercourses. Furthermore, there has to be contingency plan from the fracking companies for any possible groundwater contamination, but throughout the research there was no any traceable contingency plan which has been used in any of the countries practising hydraulic fracking. These are the reasons contributing to the opposition of hydraulic fracking by people. The researcher points out that a moratorium has been held against fracking as the Interested and affected parties were raising their concerns to the government. There had also been anti-fracking groups formed in the Karoo to fight against fracking permission. These groups have been highly supported worldwide also by the environmentalists who clearly stated that hydraulic fracking will cause groundwater contamination.

Groundwater contamination caused by hydraulic fracking is not the only major concern, the research findings indicates that people are also worried about the large amount of water required for the hydraulic fracking process. In general, mining processes requires large amount of water, and hydraulic fracking technique happens to consume more water is (between 300 000 litres and 6 million) than any other mining technique. It is clear that people are worried about the proposed hydraulic fracking in the Karoo since South Africa as a whole is a semi-arid country and the Karoo a dry area. Water required for fracking raises concerns that it will result in water shortage as this required water is the highest amongst all industries. The Karoo is known to have low annual precipitation and people there are depended on groundwater. Maltre et al., (2015) reported that water resources in the Karoo are approaching a crisis. Already the water demand has passed the stage of sustainable and balancing for human and ecological requirements. The researcher is of the view that climate change will also contribute to the water challenges in the

Karoo resulting in reduced water availability resources and variability in the water flow regime and recharge. Therefore, it would be beneficial for the hydraulic fracking companies together with the South African government to consider outsourcing water outside the Karoo. The water department needs to take full responsibility in the regulations and proper management of water use for hydraulic fracking purposes.

Groundwater contamination caused by hydraulic fracking process was not the only environmental impact identified during the research. Other identified environmental impacts include water quantity use, water quality, land degradation, noise, road damage, air pollution, road safety and maintenance and rural community impacts. These impacts further add to why most people in South Africa and across the globe are against hydraulic fracking as it poses a lot of environmental impacts.

5.3 SIGNIFICANT PUBLIC REACTION WITH REGARD TO FRACKING PARTICULARLY IN SUB-SAHARAN AFRICA

It has been evident in the findings that hydraulic fracking in the Karoo has not been given enough attention by the researchers. In support of this statement, research participants gave views on research work conducted in other countries such as USA and Canada, there was no much input given with regards to fracking in the Karoo South Africa. Furthermore to this, even the hydraulic fracking literature, quotes information which was taken from the USA studies. This can be supported because the USA is one of the very first countries to conduct fracking with successful outcomes although there were some negative failures. The literature identified that the USA has been practicing fracking for over 10 years and further took the opportunity of helping other countries by transferring fracking expertise and environmental security. Therefore South Africa can learn from USA to develop policies and conduct further research to help conduct hydraulic fracking safely. But it should be noted that records and experiments cannot just be adopted from another country, they have to be applicable to the Karoo South Africa. South Africa should learn from the USA; they have never stopped developing policies and conducting further research. Although USA had been conducting fracking for many years; they just keep on improving their expertise.

The public concern raised during this research study is if South African government have the required capacity to conduct successful hydraulic fracking. The findings revealed that resource to conduct fracking is essential for the mining process. Therefore the government has to acquire and purchase the relevant resources before any process on site can commence. The study findings further elaborate that skills can always be obtained or transferred from expects during the fracking process. Fracking is a proposed new mining technique in South Africa; meaning the government has to be ready to source the required resources, technology and skills. The government has to outsource all the capacity to conduct hydraulic fracking and these capacities can only be sourced from foreign countries which have the experience in hydraulic fracking.

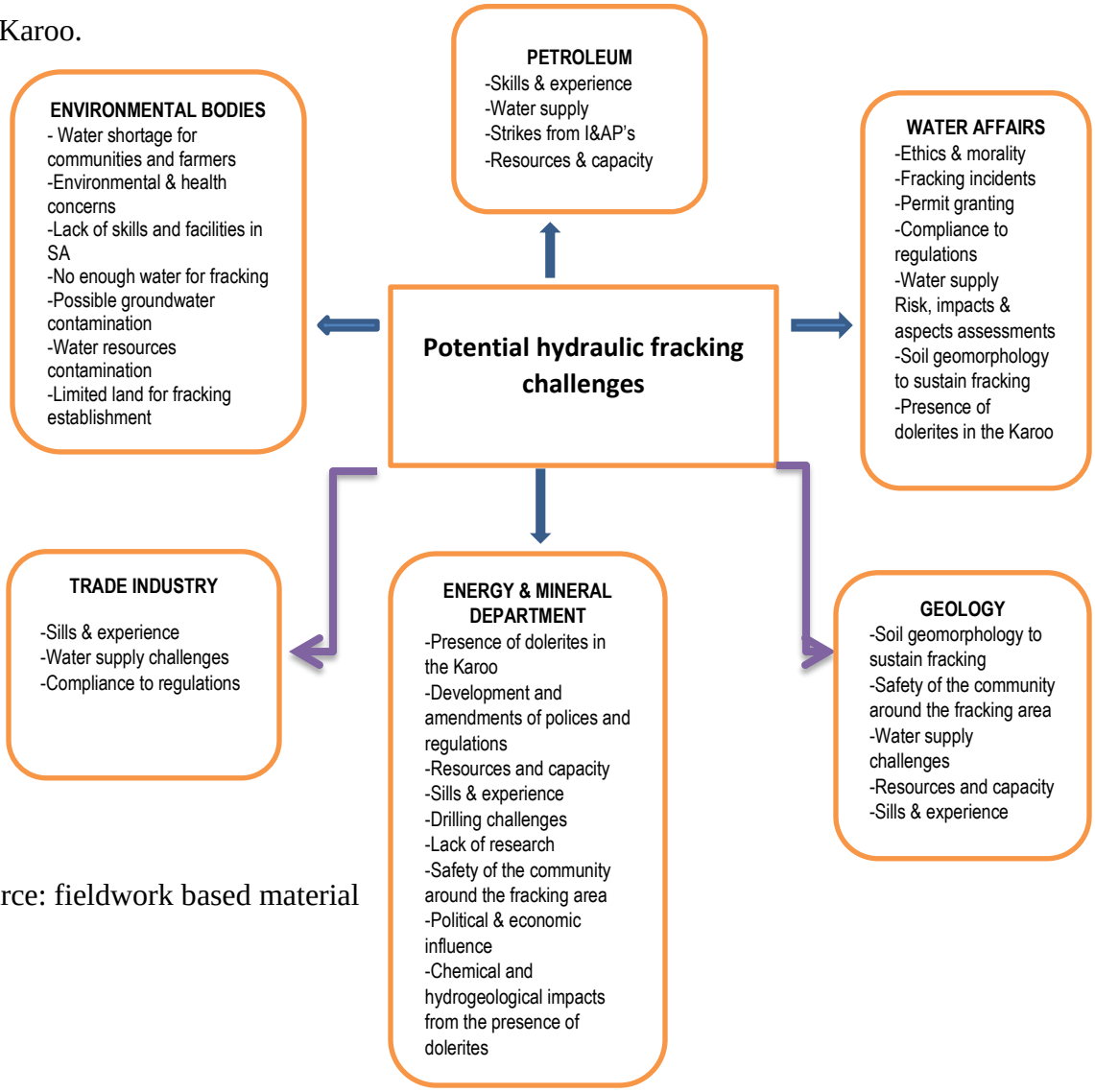
This new technique leaves South Africa vulnerable to use capacity offered by other countries which have been conducting fracking for long and therefore those countries will benefit economically. Even more, South African might have to seek financial funds or investors from other countries to compensate for this new mining technique. South African people might not benefit economically because they do not have the required skills which will leave the fracking companies employing expects from other countries. Melikoglu (2014) stated that the gas development in the USA is mature and successful. In the rest of the world including South Africa, the process is still in the nascent stages. Therefore even if USA shares the experience and resources with other countries, it does not necessarily mean that fracking in those countries will be of success. In spite of the offer of skills and resources in to South Africa from other countries such as USA, the practice and regulations need to be adapted to the Karoo. The government has to ensure that the community has some form of benefit from this mining process and the country also has to benefit economically. This can be achieved if there is some form of a lease stating the needs of people around fracking areas to be involved and hired in those fracking mines. The mines should also focus on social development for the area. Further education and skills development plays a crucial role on the economy of the country. Although South Africa does not have expects of fracking mining, preparations can be made to acquire the skills and knowledge before fracking can be granted in the country. It would be ideal if the government focuses on equipping South African resident with skills and knowledge on hydraulic fracking for the country benefit.

Although South African government might have to outsource resources from other countries, the study has showed that hydraulic fracking still has possible economic benefit for South Africa. The expected benefits identified include the creation of jobs, reduction in carbon footprint economic growth and energy independency. Mining is required for the energy supply of electricity also for the economic. Coal mining used for the supply of energy had been a growing mining sector in South Africa and there had been evident environmental impacts from these processes. South Africa is also one of the countries facing challenge to meet the future energy demands of an expanding economy while improving standards of living. Since the new democratic government of 1994 people from across the countries moved to South Africa to seek for better jobs and life. This resulted in the population of the country highly increasing as the life standard is affordable in South Africa. As the population increases, there is also a need for the energy supply to the households, business sectors and all any other operations which requires energy supply. South Africa has been experiencing major energy supply problem since 2007 due to the growing population density and the economic sector.

Southern African countries are facing a challenge to provide adequate affordable electricity to their people. Energy companies have been promising people better jobs, economic growth and reduced dependence on coal-fired electricity, but there has not been much change experienced in these countries. The ideal proposed solution is the developing of natural gas energy supply to help meet the increased energy demands. Natural gas is viewed as a transitional clean energy future that will help replace conventional mineral oil and coal. Coal is used mainly as the primary energy input to generate electricity in South Africa is under major reviews as it brings pollution challenges with. The coal impacts include the release of Sulphur in the mining process, carbon dioxide and mercury vapour in the flue emissions of the power station (Wenig *et al.*, 2002). The detailed regulatory measures of hydraulic fracking of natural gas within South Africa could contribute reduction of heavy dependence on coal in the energy input for electricity generation (Wenig *et al.*, 2002). It could also minimise on the consequences suffered from the release of carbon emissions with natural gas being a cleaner source of energy. The natural gas could also shape the future mix of energy generation and be a mechanism to reduce the demand for electricity and other source of energy.

Even if there can be possible economic benefits acquired from hydraulic fracking process there are possible challenges which will always be expected. On diagram 4.1 below, the research participants identified some of the possible challenges. The three departments which include energy & mineral, the environmental bodies and the water department stated more challenges which could result from fracking. All organisations identified water supply for hydraulic fracking process and the skills required as the most detrimental challenges that South Africa faces to conduct the hydraulic fracking process. Participants from the department of energy & minerals identified challenges which are closely related to the drilling operations including the chemical and hydro geological impacts, drilling challenges, lack of research, policies and regulations for the fracking operations.

Diagram 4.1: A summary of participants views on anticipated hydraulic fracking challenges in the Karoo.



Source: fieldwork based material

5.4 WHAT LEGAL AND INSTITUTIONAL FRAMEWORKS EXIST ON GROUNDWATER AND REGULATE HYDRAULIC FRACKING IN GENERAL?

MPRDA, NEMA, Water act and the South African Constitution has been identified in the study as the main regulators for hydraulic fracking in the Karoo and the MPRDA was identified as the main regulation. In the actual fact, the MPRDA is accountable for managing mining activities in South Africa. Analysis of the study shows that people only know just a few legislations governing hydraulic fracking in South Africa. People should know The MPRDA as it is involved in the planning and revision of its act and to cover explorations of the proposed hydraulic fracking in the Karoo. The revision of the MPRDA was announced through a government gazette notice released in 2013, ensuring that I&AP'S know about the revision. The environment bodies have been very active fighting against the proposed hydraulic fracking in the Karoo. They referred to NEMA and water act to dispute fracking in the Karoo therefore most people had to hear and know about these regulations.

Centre of environmental rights (2013) stated that South Africa has inadequate mining regulations. Monitoring and enforcement have continued to impose financial, health and environmental costs on the society and its future. Fracking techniques must be regulated by appropriate and broad regulatory management. Centre of environmental rights (2013) reported that the regulation of the environmental impacts posed by fracking must comply with the available legal framework. This includes fundamental rights of constitution, the National Environmental Management Act of 1998, the National Water Act of 1998, the national Environmental Management: Waste Act of 2009 and the National Environmental Management: Air Quality Act of 2004.

In spite of regulations related to hydraulic fracking, it is the responsibility of the South African government to ensure that these regulations are revised and do cater for the explorations of shale gas. Centre of environmental rights (2013) adds that to manage environmental impacts of fracking in South Africa effectively, the regulations must comply with the best international practice and regulatory requirements. USA conducted successfully fracking for over 10 years. The government must not only consider the American Petroleum Institute to regulate the proposed fracking in the Karoo. Therefore, Minerals and Petroleum Resources Development Act

of 2002 will explore shale gas in South Africa and be regulated by petroleum Agency SA. The biggest challenge that South Africa faces is that fracking is a new mining technique, there are no regulations developed specifically for these process. In spite of the development or amendment of the regulations to hydraulic fracking, various laws required the proponent before obtaining planning and authorisations. The regulations and policies should be specific to South Africa and the Karoo; not only to adopt policies from other countries such as USA that have been practising fracking for over many years.

Sourcing of vast water required for fracking process, flow back water treatment and the potential groundwater contamination during the fracking process have been associated. It is refereed to be managed by the National Water Act of 1998 and the Waste Act of 2009. Therefore before fracking process can be permitted in South Africa, critical reviews and development of regulations and policies must be reflected by the government cabinet.

5.5 GAPS IN LEGISLATION

Research investigations showed that there were gaps identified in the MPRDA and they were amended in 2013, the governing of exploration and exploitation of petroleum resources were augmented. Although regulations are being amended for hydraulic fracking, it would be ideal to develop a policy specific for fracking and the use and protection of water resources. Groundwater studies and atlas can be studied to be incorporated in the hydraulic fracking policy. The analysis showed that South Africa is ready to adapt fracking legislations from the USA as it is one of the countries that have been practising fracking for over 10 years. According to the researcher, these legislations might have gaps because there were not drafted specifically to suit the geomorphology of South Africa. Therefore it would be appropriate if these legislations can only be used as a guideline to develop something specific to South Africa. The researcher's opinion is that the water act should be amended to state clearly the limits on the amount of water when applying for a water license. The analysis showed that the existing legislations are not sufficient to protect groundwater from hydraulic fracking processes. The main reason to this is lack of monitoring and cooperative governance between the departments responsible for regulating hydraulic fracking. In the view of the current legislations, it is important to amend legislations for clear responsibilities and ensure that

every department delivers their requirements. The amendments will also help to ensure all fracking requirements are identified for proper monitoring and compliance.

5.5.1 An overview of the research topic

This research was based on the exploration of potential impacts of hydraulic fracturing on groundwater contamination in the Karoo. The research study further looked into the perspectives on institutional capabilities in water management in South Africa. The study acknowledges that the research study was not conducted at the actual site Karoo but it was based on the explorations. The researcher acknowledges the studies that have been conducted by other researchers on hydraulic fracking and particularly in the Karoo South Africa.

This research was conducted to contract an overview and better understanding of the groundwater resource studies particularly looking on water recharge and its sustainable yield. Hydraulic fracking is a new mining technique in South Africa. The interest of the research was also to assess the institutional capabilities of the government to conduct and govern a successful hydraulic fracking process. Before the research study started, the researcher already knew that the potential impact of fracking is groundwater contamination. This speculation of groundwater contamination was evident by the research participants as they raised concerns of groundwater contamination as the major issue associated with hydraulic fracking. The literature reviewed during the study also confirmed groundwater contamination as the main environmental impact of hydraulic fracking. However, there were gaps identified in the literature reviewed of the study. The literature indicated that groundwater contamination can be accidental if the well drilling and the fracking process are not conducted accordingly. It is identified in the literature that groundwater contamination can be from flow backs and treatment rather the actual hydraulic fracking technique. Groundwater contamination occurred in the USA during their early days of fracking has improved drastically with the number of incidents low.

The research also identified that the South African government and its various departments has been working on developing and amending regulations and policies to adopt hydraulic fracking in the country. Before there were no regulations for hydraulic fracking, this caused the public to

lay out their concerns and challenge the government decision to grant fracking explorations in the Karoo. The South African government had to place a moratorium against fracking in 2013. More studies are desirable to get a better view of fracking in the Karoo and to develop applicable regulations before the actual fracking can commence in the Karoo. I&AP's which consist mostly of the environmental groups and the Karoo anti fracking groups is totally against fracking in the Karoo.

5.6 CONCLUSION

The discussion chapter highlights the key issues of the research study. The data collected is analysed and discussed to answer the research question. In South Africa, hydraulic fracking is a new proposed mining technique and there were no legislations in place to govern this mining process. Currently there are legislations which are under review and development to address also hydraulic fracking. Researchers and different states are working together to take a number of studies before obtaining planning and authorization of the laws. The government should also be responsible and be involved in the review and development of these regulations and policies. Further to the investigation, there are some of the regulations which are being reviewed, the government issued notice to inform changes on these regulations. In 2013, the MPRD released notice 1031 of a draft regulations focused on the "augment gaps identified in the current regulatory framework. The exploration and exploitation of petroleum resources, particularly in relation to hydraulic fracking, practices and standards will enhance safe exploration and production of petroleum" (Mineral and Petroleum Resources Development Act, 2002 Act No. 28 of 2002 notice 1032 of 2013).

Furthermore, different anti-fracking groups from national and international came together to fight the government against the granting of hydraulic fracking in the Karoo. The anti-fracking groups believed that the government and those organisations intending to use fracking as method to mine gas in the Karoo, have not been transparent about the hydraulic fracking information. The research information identifies that there is controversy amongst different departments with unified agreement on the actual or potential impacts of fracking on groundwater contamination

and other environmental impacts. In literature review, Cartwright (2013) identified that regardless of 'protects' against hydraulic fracking, unconventional gas has been brought into production in many regions despite a poor understanding of its various potential impacts. This illustrate that the fracking companies are willing to continue with the fracking process regardless of the concerns raised or the research study results. The research also reported that people gave their view on hydraulic fracking based on the knowledge and experience of the USA hydraulic fracking. They generalised the incidents that occurred in the early days of fracking in the USA in the case of South Africa. Other government departments believe that further assessments of hydraulic fracking should be made before a decision or granting of permit can be allowed. Research study, technology and legislations have improved over the years and it was proven in the USA as they have reduced hydraulic fracking incidents over the years.

Nilsson & Randhem (2008) indicates that chemical hazards which arise from chemical pollutants in water, solid wastes and air with the most common substances being carbon monoxide and dioxide, oxides of sulphur, nitrogen oxides and fluorine compounds. This is an indication that there is potential groundwater contamination resulting from the hydraulic fracking process. Due to all concerns raised by the public and anti-fracking group, the government had to hold a moratorium against hydraulic fracking in South Africa. The South African public believed that they will not benefit in any form from the fracking exposures in the Karoo. So, it can go wrong during this process as the government do not have the required resources and skills to conduct successful fracking. The Karoo community will then be left with hydraulic fracking skeletons and environmental impacts to deal with in a long run.

The primary conclusion reached in this study is that South Africa's regulatory framework must be robust enough to ensure that, if hydraulic fracturing associated with shale gas exploration and exploitation were approved, any resultant negative impacts would be mitigated. This will require a comprehensive review of the adequacy of the existing framework in order to identify any shortfalls or omissions and to ensure that it is sufficiently detailed and specific. The use of existing regulations from mature regulatory environments to inform the development of South African regulations in this matter is recommended.

CHAPTER SIX

CONCLUSIONS AND RECOMMENDATIONS

6.1 INTRODUCTION

This chapter aims to bring together fundamental conclusions and the key lessons learnt about the proposed hydraulic fracking in the Karoo South Africa. The first key finding presents an overview of the potential groundwater contamination. The second key finding is an overview on institutional capabilities in water management. It concludes by identifying the recommendations for future research and some initiatives that can be executed with the assistance of the relevant hydraulic fracking departments and other interested stake holders to ensure successful hydraulic fracking in the Karoo.

6.2 SUMMARY OF THE RESEARCH KEY FINDINGS

6.2.1 Potential impacts of groundwater contamination in the Karoo

The main argument presented in this research is that of the potential impacts of hydraulic fracking on groundwater contamination in the Karoo. The investigation reveals that groundwater contamination is the major concern that people have on hydraulic fracking. The fracking incidents and lessons learnt in the USA throughout the years of operating hydraulic fracking bring concerns that the very same incidents might also occur in the Karoo. This research also identified that even though there are concerns raised with regards to groundwater contamination, there is no significant research that states that hydraulic fracking will cause groundwater contamination in the Karoo. There is just generalization based on the experience of the USA that fracking will cause groundwater contamination. It was also observed that there is disagreement amongst relevant hydraulic fracking departments with regards to the potential groundwater contamination. Other departments believe that incidents can only occur if the planning and implementation of the hydraulic fracking well is not correct. A decision on whether or not hydraulic fracking will cause groundwater contamination cannot be based on speculations or

lessons learnt from other countries, there has to be an assessment of the actual implication of this method.

This research was based on the theoretical claim and it was identified that groundwater contamination is caused by poor well casing causing leakage of fracking fluids and flow back storage tanks leaks. In support, skills and technology can help combat the risk of groundwater contamination. The government and the gas companies need to work together to determine the right tools to be used to conduct successful hydraulic fracking. Furthermore, the lessons learnt from other countries also helps to avoid repeated incidents and they can also be used for improvement opportunities. Considering that the Karoo it's a different biome on its own, all the planning and development of hydraulic fracking tools should be specific to the Karoo.

6.2.2 Perspectives on institutional capabilities in water management in South Africa

The investigation revealed that South Africa did not have an existing legal framework to govern the operation of hydraulic fracking at the proposed Karoo. Hydraulic fracking in South Africa is a new mining technique and it is very specialized that it needs to be regulated by appropriate and comprehensive regulatory regime. The major concern of I&AP's had to do with the protection of groundwater, water bodies and the environment. But the South African government was ready to proceed with hydraulic fracking in the Karoo although the public was disputing it and there were no existing legislations in place to be used to monitor the fracking processes. Department of Mineral and Petroleum Resources Development had released a notice 1031 in 2013 of the draft regulation to augment gaps in the existing regulation to also cater for hydraulic fracking; this shows that there were no current legislations in place. Although this regulation was amended for the regulatory framework of governing the explorations, more research studies are required to support these legal frameworks.

South Africa experienced bad history of noncomplying mining operations which dates back to many years. The cause to such was due to inadequate mining legislations which were not enforced or monitored during the operations. This is also a reason to why the public is resisting permitting hydraulic fracking in the Karoo which is already known to have the potential of

groundwater contamination. The fear is that incidents such as leaks during the operations could emerge and communities around the hydraulic fracking areas will be highly affected. The impact could also be severe that even after the shutdown of the mine the community will be left to deal with it and it can also affect the future generations. The constitutional rights of humans should always be protected, the decision of permitting fracking in the Karoo cannot only be made by the government, all I&AP's views should be respected and addressed.

This research study identified existing regulations in South Africa that can forms part of governing and monitoring the processes of hydraulic fracking. These regulations are; Mineral and Petroleum Resources Development Act No. 28 of 2002, Environmental Management Act No. 107 of 1998, the National Water Act No. 36 of 1998, Waste Act of 2009, Air Quality Act of 2004 and the Constitution of Republic of South Africa, 1996. The investigation probed the effects of observed decrease of incidents in the USA throughout the years of amending and developing legal framework to govern and improve the compliance and monitoring of hydraulic fracking processes. Same as with South Africa, these identified regulations can be amended to suit the operations of hydraulic fracking. To achieve a successful operation of fracking, different expects and researchers need to come together and draft or amend regulations to be practical and specific for hydraulic fracking operations in South Africa. Throughout the research study and explorations, it was identified that hydraulic fracking has the potential to cause groundwater contamination with references of incidents that occurred in the USA. But this does not necessarily prove that the same incidents can occur in South Africa and there was no any literature clearly stating that hydraulic fracking causes groundwater contamination.

6.3 RECOMMENDATION OF FURTHER RESEARCH STUDY

As this research study was based on the explorations, not the actual research site which is the Karoo in South Africa; it would be ideal to conduct future research at the actual study area whereby it would be possible to collect samples directly on site. It would be best practice to use information and samples available in the Karoo and South Africa as a whole rather than using information accumulated from other countries such as the USA and Canada that have been

conducting hydraulic fracking for over 10 years. The research studies that can be done in the future can include research on the Karoo biome and its environment, water analysis and the geomorphology of the area. It was observed during the research study that hydraulic fracking in South Africa is a topic that has not received sufficient consideration from the researcher.

The research data was collected from participants mostly from the government departments including the energy and mineral, environmental bodies, trade industry, petroleum, geologists and participants from the department of water. Therefore other studies can involve also private sectors and the gas mining companies together with their specialists to acquire relevant information on hydraulic fracking operations. Public participation can be arranged with the I&AP's in the Karoo, this will assist to get the actual information, concerns, questions and solutions with regards to the proposed fracking in the Karoo. Intervention from different departments and the public will assist in setting and planning successful fracking in the Karoo.

The study needs to focus on the legal frame work that can be used to govern hydraulic fracking in South Africa. These studies can be used to review regulations, identify the gaps and determine if those regulations needs to be amended or changed to support and govern hydraulic fracking in South Africa. The study can also make comparison with those legal frame works from USA to assess if there are any sections that can be adapted to be implemented in South Africa. The study results can propose actions to be taken to strengthen decision making on whether or not to permit hydraulic fracking in the Karoo South Africa.

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APPENDIX A

Schedule/ structure of the research dissertation

Milestones	YEAR 1				YEAR 2				YEAR 3				YEAR 4			
	2014				2015				2016				2017			
	J	A	J	O	J	A	J	O	J	A	J	O	J	A	J	O
	F	M	A	N	F	M	A	N	F	M	A	N	F	M	A	N
	M	J	S	D	M	J	S	D	M	J	S	D	M	J	S	D
Phase I: Project Development																
Research topic																
Preliminary scan & literature review																
Problem statement, aims, objectives and questions																
Theoretical framework and literature review																
Compile Study Region and Methodology																
Present research proposal																
Submit research proposal																
Ethical & policy consideration of the Wits University																
Phase 2: Data Collection and Analysis																
Fieldwork (data collection/conduct interviews)																
Extracting and compiling information from the questionnaires																
Data capturing and editing																
Data analysis, synthesis and interpretations																
Phase 3: Writing final dissertation																
Assembling the papers																
submitting the final dissertation																

APPENDIX B

Participant information sheet

Research Title:

Exploring potential impacts of hydraulic fracturing (fracking) on groundwater contamination in the Karoo. Perspectives on institutional capabilities in water management in South Africa.

Key words: Natural gas from shale, groundwater contamination, Water management, public acceptance

Research Investigator: Khumbelo Britney Chisebe

Student number: 0705601T

Study information:

University: University of the Witwatersrand

Faculty: Faculty of Science

School: School of Geography, Archaeology and Environmental Studies

Study Program: MSc in Environmental Management

Purpose of the research

My name is Khumbelo Britney Chisebe, a Masters student in the School of Geography, Archaeology and Environmental Studies at the University of the Witwatersrand, Johannesburg, South Africa. This is an invitation to participate in completing the questionnaires of a research thesis project which is the part of the requirement for Masters of Bachelor of Science in Environmental Management. Before you agree to participate, it is important that you read and understand the purpose of the study. This information sheet is to help you decide if you would like to participate. Do not hesitate to ask any question you might want to. You are free/not to participate and still free to skip any question and withdraw from the study at any stage and this will not be held against you. If you decide to take part in this study, you will be required to sign a consent form confirming that you understand and accept to be part of the study. You will also be given a copy to keep.

Purpose of the research and selection of the interviewees

The aim of the study is to investigate the extent to which current institutional set up in South Africa can deal and address potential environmental challenges that are associated to hydraulic fracturing. You have been invited to participate on this research because you have been identified as the key informant with knowledge and professional background related to the research aim. The information provided will be used solely for academic purposes.

Procedures

The research will consist of semi-structured interviews, and it is foreseen to last between one to two hours. The interviews will be conducted as face to face or emailed to you as the participant. The face to face questionnaires will be administered in your workplace or at a location of your choice. The interview questions will relate to your knowledge, feelings and issues associated with hydraulic fracturing, the potential impacts of groundwater contamination and the institutional capabilities of water management in South Africa.

Possible risks inconvenience and discomfort

There are no any foreseen risks involved in participating in this study. Your involvement in the study is voluntary and you may withdraw your participation from the study at any given time. Refusal to participate in the study will not affect your relationship with the University of the Witwatersrand. You are also free to stop the interviewer or skip any questions that you may find offensive or uncomfortable to answer. All identity and information given will be treated in confidentiality.

Benefits of the research

Your participation in the study will benefit the research. Note that to participate in this research study is voluntary; therefore there will be no any remuneration or gifts given to the interview participation. All the information and data collected will be analysed and used as part of the final thesis report to accumulate a master's degree in the faculty of Science at the University of the Witwatersrand. The research results may also and possibly be published in educational journals or used as part of presentation materials at conferences and workshops.

Confidentiality/ Anonymity

The data collected will not contain any personal information about you except for your organisation profile and your role in the organisation; it will be in an anonymous format. No one will link the data you provided to the identifying information you supplied and all documentation will be kept strictly confidential. At no time will any specific comments be attributed to any individual unless specific agreement has been obtained beforehand. The data you provided together with that of other participants will be used for academic purposes only. They will be compiled into a Master's thesis and submitted to the Faculty of Science, University of the Witwatersrand.

Research contact details

For further information regarding the research or the implication of your participation, you can contact me or my supervisor will be glad to answer your questions. If you want to find out about the final results of this study, you can state so then future communications will be made with you.

Study investigator	**Research Supervisor**
Khumbelo Britney Chisebe	Dr Danny Simatele
Email address: Khumbelo@student.wits.ac.za	Danny.simatele@wits.ac.za
Cell no: +27 72 409 6424	Phone No: + 27 11 717 6515

Declaration/ consent by participant

I hereby confirm that I have been informed about the research study by the researcher Miss Khumbelo Britney Chisebe. I have had an opportunity to ask questions about the participation in the study. I understand the purposes and procedures of the research described in the information sheet.

I do understand that by agreeing to be involved in the research I will be involved in interview questions. I understand that without prejudice I can withdraw my participation or skip any questions in the study. I therefore agree to participate in this research project. I am aware that the results of the study will be anonymously processed and may at any stage without prejudice withdraw my consent and participation in the study.

I do agree to be audio-recorded during the interview questions. ☐ *(Tick if appropriate)*

I do not agree to be audio-recorded during the interview questions. ☐

Interviewee/ Participant

Signature_____ Date_____

APPENDIX C

Interview questions

This interview questions are to be administered to the energy and mineral experts, state government agencies, environmentalists and water resources management.

Introduction

"Fracking" has become a common word to denote hydraulic fracturing. It is a method employed in accessing shale gas. This study seeks to investigate the extent to which current institutional set up in South Africa can deal with and address potential environmental challenges and water management issues that are associated with fracking.

Format: Semi-Structured Interview

Interviewer: Khumbelo Chisebe

Date: _____ **Time**: _____

1. **Project profile**

1.1. What is the name of your organization?

_____

1.2. Can you tell me a bit about your organization, what does your organization do?

_____

1.3. What is the history or background of your organization?

_____

1.4. What are the concerns as an organization with regard fracking in the Karoo?

_____

2. **Perception of fracking**

2.1. What is your knowledge about hydraulic fracturing?
Probe: what is fracking all about to you?

_____

2.2. What potential benefits do you expect fracking will bring for South African economic development?
Probe: How will fracking benefit the South African economy?

_____

2.3. From your point of view, what could be the challenges of fracking?
Probe: What are the negative issues related to fracking?

_____

3. Fracking in the Karoo

3.1. What would be your opinion on the amount of water required for hydraulic fracturing operations?
Probe: Does the Karoo have enough water resources to conduct fracking?

_____

3.2. Which lessons can be learned from other studies in terms of groundwater contamination from hydraulic fracturing operations?
Probe: What are the impacts of fracking on groundwater contamination?

_____

3.3. How do you feel about fracking flow back disposal methods?
Probe: Do you know anything about the fracking flow back disposal methods?

_____

3.4. What is your view on the potential environmental impacts that could emerge at the Karoo from hydraulic fracturing process (For example: Water supply, storage, treatment; air pollution; road damage and erosion)

_____

4. Institution response to fracking

4.1. Are you able to identify any specific policies which exist in South Africa with regard to fracking and groundwater contamination?
Probe: Do you know any specific fracking related polices which exist in South Africa?

_____

4.2. How can institutional framework engagement be organized to provide enough protection to the local water supplies and sources from potential contamination due to fracking process?
Probe: Can the existing institutional framework provide adequate protection on groundwater contamination caused by fracking process?

_____

It has been argued by Knudsen (2012) that fracking technologies have made it possible to produce natural gas extraction in shale places that were once unreachable.

4.3. From your point of view, does the South African Government has the required capacity of the following to conduct hydraulic fracturing?

(a) Skills	Yes ☐	No ☐	*(Tick the appropriate box)*
(b) Resources	Yes ☐	No ☐	
(c) Technology	Yes ☐	No ☐	

4.4. Does the state or local government have any information campaigns to inform the public about fracking development?
Probe: Is the government doing enough to keep the public posted about the fracking developments?

_____

4.5. Based on your interactions with the general public, what has been the most significant public reaction with regard to fracking?
Probe: How does the public feel about the proposed fracking in the Karoo?

_____

4.6. In your own view, which parties or organizations would you consider play a role in the success or failure of fracking?
Probe: Which parties are mostly responsible for success or failure of fracking?

_____

5. Further information

5.1. Based on our interview are there any other questions or anything you would like to add?

_____

5.2. Is there anyone else that you recommend I talk to? If yes please include the contact details

_____

APPENDIX D

Ethics clearance certificate

Research Office

HUMAN RESEARCH ETHICS COMMITTEE (NON-MEDICAL)
R14/49 Chisebe

CLEARANCE CERTIFICATE	**PROTOCOL NUMBER: H15/06/17**
PROJECT TITLE	Exploring potential impacts of hydraulic fracturing (fracking) on ground water contamination in the Karoo. Perspectives on institutional capabilities in water management in South Africa
INVESTIGATOR(S)	Ms K Chisebe
SCHOOL/DEPARTMENT	GAES/
DATE CONSIDERED	19 June 2015
DECISION OF THE COMMITTEE	Approved unconditionally
EXPIRY DATE	12 July 2018

DATE 13 July 2015 **CHAIRPERSON** _____
(Professor J Knight)

cc: Supervisor : Dr D Simatele

DECLARATION OF INVESTIGATOR(S)

To be completed in duplicate and **ONE COPY** returned to the Secretary at Room 10005, 10th Floor, Senate House, University.

I/We fully understand the conditions under which I am/we are authorized to carry out the abovementioned research and I/we guarantee to ensure compliance with these conditions. Should any departure to be contemplated from the research procedure as approved I/we undertake to resubmit the protocol to the Committee. **I agree to completion of a yearly progress report.**

_____ _____/_____/_____
Signature **Date**

PLEASE QUOTE THE PROTOCOL NUMBER ON ALL ENQUIRIES