Towards a strategy for sinkhole risk reduction: The case of the Merafong Local Municipality

TI Moshodi

18035361

Mini-dissertation submitted in fulfilment of the requirements for the degree *Masters* in *Development and Management* at the Potchefstroom Campus of the North-West University

Supervisor: Mr C Coetzee

November 2014

DECLARATION

I declare that: "***Towards a strategy for sinkhole risk reduction: The case of the Merafong Local Municipality"*** is my own work; that all sources used or quoted have been indicated and acknowledged by means of complete references, and that this mini-dissertation was not previously submitted by me or any other person for degree purposes at this or any another university.

SIGNATURE **DATE**

ACKNOWLODGEMENT

Firstly, I would like to praise and thank God, the all mighty, for giving me the opportunity to experience learning at the master level as well as the strength to overcome all the challenges encountered during the study.

Then I would like to thank my study leader, Mr Christo Coetzee, for providing directions when I lost and confused as well as for being patient with me. Thank you for your constructive criticism and the ability to provide feedback in time. Your insight has improved my thinking, analysing and reasoning capacity. And your higher standard has taught me to be patient, persevere as well as to work hard in order to prosper in life.

I would also like to thank my parents (Mr Motsamai Moshodi and Mrs Matlakala Moshodi), my soulmate (Ms Ronel Mohanoe) and friends (Mr Gwai Moseki, Mr Emmanuel Montwedi, Mr Isaac Mohlakudi) for providing unending support and understanding during the study. And to my late sister, Ms Pontie Makaudi, I was hoping that you would be with me when I receive this prestigious qualification but may your soul rest in peace and I will always miss your ever laughing face.

Also extend a special appreciation to Mrs Farzanah Loonate and Mrs Mpho Letheya for their motivating and restoring words during the moments were quitting was the only option in my mind.

Lastly, I would like to thank all the officials of the Merafong Local Municipality and the residents of Khutsong Location for their willingness to participate on the study. Had it not being by you, this study would have been impossible to accomplish. And, also the Merafong Local Municipality for funding the last year of my studies. For those who contributed in positively in my life but I did not mention by name, may the grace of God bless and guide you to realise your goals as well.

ABSTRACT

The discovery of gold and diamonds, followed by coal during the late 19th century changed the entire economic structure of the Southern African region (Booyens, 2008:17; Van Eeden et al., 2009; Jurad, et al., 2010:78–79; Winde & Stoch, 2010; Peatfield, 2003:355). Despite the many positive developments brought about by gold mining, there are also a number negative aspects associated with mining. These include environmental degradation (specifically water pollution and the dewatering of dolomitic compartments which is strongly associated with sinkholes) as well as health threats for local inhabitants (such radon emission, dust and exposure to radiation).

Mining in the Far West Rand, wherein the study area falls under, occurs on dolomitic land (Buttrick & Van Schalkwyk, 1998; Swart et al., 2003; Watermeyer, 2001; Ngcobo, 2006). Dolomite can be defined as a soluble carbonated bedrock. Constant exposure of dolomite to rainwater together with negative impacts associated with human activities (such as ground water extraction, leakage from water pipes and sewerage systems) dissolve the rock over time because these substances penetrate through joints of the rock to form openings beneath the surface – which may result in sinkholes (Swart et al., 2003; Kirsten et al., 2006; Zhou, 1997:50; Van Eeden et al., 2007).

Sinkholes are likely to occur without warning, although cracks in walls are often early signs of danger. They are either caused by the hollowing out or formation of a void below the earth's surface as a consequence of normal geological processes or they may have anthropogenic causes. Anthropogenic causes such as the construction of roads, township development and associated services, groundwater extraction and groundwater recharge may also give rise to the formation of sinkholes (Haarhof, 2011; Buttrick & Van Schalkwyk, 1998; Ngcobo, 2006; Watermeyer et al., 2001; Watermeyer et al., 2002; Swart et al., 2003; Gutierrez, 2006; Buttrick et al., 2011).

The Merafong Local Municipality (MLM) is located within the West Rand District Municipality (WRDM), in the Gauteng province of South Africa. Its boundaries enclose some of the richest gold mines such as Western Deep Levels, Driefontein

West and East, Blyvooruitzicht and Doornfontein (Van Eeden, 2006:417). In spite of the relative wealth and economic activities generated by mines, a number of serious environmental issues such as sinkholes in this area started to emerge at an alarming rate after gold mines have been granted permission by the government to drain dolomitic compartments (Van Eeden, 1997; Van Eeden, 2003; Swart et al., 2003; Coetzee et al., 2004).

The occurrence of sinkholes in the MLM is historically associated with loss of life and damage to infrastructure. Some of the catastrophic events associated with the dewatering of dolomitic aquifers within the Merafong area include the following:

- Sinking of the West Driefontein crushing plant as well as the business sector of the Carletonville Township (known as Khutsong) into sinkholes;
- Evacuation of inhabitants of the farm Bank due to unstable surfaces caused by ground movement;
- The death of a family of five at Blyvooruitzicht due to a sinkhole;
- Drying up of boreholes used for farming activities as well as cracking walls of local houses and the deterioration of infrastructure (Winde & Stoch, 2010; Van Eeden et al., 2003; Van Eeden, 2006; Ngcobo, 2006; Swart et al., 2003).

Given the extent of damage caused by sinkholes due to mining and human activities, the current study focuses on the causes and impacts of sinkholes, and also on possible strategies that can be adopted by the residents of MLM and the City Council in order to reduce the risks associated with sinkholes. The sinkhole risk reduction strategy also proposes a system that will eliminate or mitigate the occurrence of sinkholes by proactively monitoring and responding to aspects that lead to the formation of sinkholes.

TABLE OF CONTENTS

Chapter 1

Orientation and problem statement

1.1 Introduction

The discovery of gold and diamonds followed by coal in the late 19th century changed the entire economic structure of the Southern African region (Booyens, 2008:17; Van Eeden *et al*., 2009; Jurad, *et al.*, 2010:78–79; Winde & Stoch, 2010; Peatfield, 2003:355). Within this context, rapid expansion of the mining industry resulted in increased industrialisation which, in turn, contributed to the economic growth of South Africa. Gold mining has since then become the foundation of South Africa's economic growth. South Africa has been producing up to 35% of the world's gold (Peatfield, 2003; Van Eeden, 2009; Booyens, 2008:17). Despite the positive developments brought about by gold mining, there are also a number negative aspects associated with mining. These include environmental degradation (specifically water pollution and the dewatering of dolomitic compartments which is strongly associated with formation of sinkholes) as well as health threats for local inhabitants (such as radon emission, dust and exposure to radiation) (Winde & Stoch, 2010; Van Eeden *et al.*, 2003; Van Eeden, 2006). Mining in the Far West Rand, which the study area falls under, occurs on dolomitic land (Buttrick & Van Schalkwyk, 1998; Swart *et al.*, 2003; Watermeyer, 2001; Ngcobo, 2006).

Dolomite can be defined as soluble carbonated bedrock (Swart *et al.*, 2003; Kirsten *et al.*, 2006; Zhou, 1997:50; Van Eeden *et al.*, 2007). Constant exposure of dolomite to rainwater together with negative impacts associated with human activities (such as ground water extraction, leakage from water pipes and sewerage systems) dissolve the rock over time because these substances penetrate through the rock joints to form openings beneath the surface – which may result in sinkholes (Swart *et al.*, 2003; Kirsten *et al.*, 2006; Zhou, 1997:50; Van Eeden *et al.*, 2007). A sinkhole is a depression on the ground that forms as a result of the dissolution of the underlying soluble rocks; it may also develop when a cave roof collapses (Monroe *et al.*, 2007:512; Strahler & Strahler, 2005:768; Mussett & Khan, 2000). Sinkholes are

typically cylindrical or conical in shape and may vary from 1 - 50 meters in diameter, while the depth may also vary between 1 - 50 meters (Buttrick & Van Schalkwyk, 1998; Zhou & Beck, 2007; Buttrick *et al.*, 2011; Li & Zhou, 1999; Watermeyer, 2001; Gutierrez *et al.*, 2007; Monroe *et al.*, 2007:512; Strahler & Strahler, 2005:768; Mussett & Khan, 2000).

Sinkholes are likely to occur without warning, although cracks in the houses' walls are often early signs of danger. They are either caused by the hollowing out or the formation of a void below the earth's surface as a result of normal geological processes (see Figure 1) or they may have anthropogenic causes. Anthropogenic sinkhole formation occurs under the following three conditions: the right geotechnical conditions, inappropriate development relative to the geotechnical conditions, and adequate rainfall (Buttrick & Calitz, 1995; Buttrick & Van Schalkwyk, 1995; Schoning, 1996; Wolmarans, 1996). Furthermore, anthropogenic causes such as construction of roads, township development and associated services, groundwater extraction and groundwater recharge may also give rise to the formation of sinkholes (Haarhof, 2011; Buttrick & Van Schalkwyk, 1998; Ngcobo, 2006; Watermeyer *et al.*, 2001; Watermeyer *et al.*, 2002; Swart *et al.*, 2003; Gutierrez, 2006; Buttrick *et al.*, 2011).The following sections will describe the geographic location of the study area as well as the causes and impacts of sinkholes.

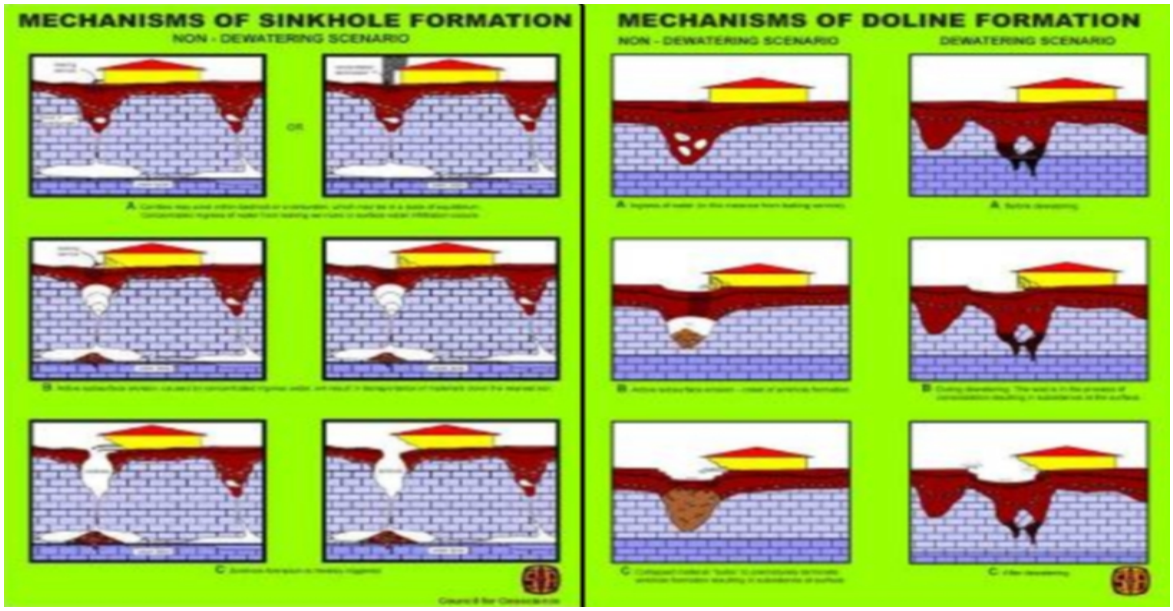

Figure 1: Mechanism of sinkhole formation (Adopted from Council of Geoscience, 2012)

The Merafong Local Municipality (MLM) is located in the West Rand District Municipality (WRDM) in the Gauteng province of South Africa (see Figure 2). Its boundaries enclose some of the richest gold mines such as Western Deep Levels, Driefontein West and East, Blyvooruitzicht and Doornfontein (see Figure 3) (Van Eeden, 2006:417). In spite of the relative wealth and economic activities generated by mines, a number of serious environmental issues such as sinkholes began emerging at an alarming rate in this area after the government granted gold mines permission to drain dolomitic compartments (Van Eeden, 1997; Van Eeden, 2003; Swart *et al.*, 2003; Coetzee *et al.*, 2004). The government made these concessions in the 1950s to enable mining activities to take place at deeper levels in the interest of greater profit and increased tax revenue (Ngcobo, 2006; Van Eeden, 1997; Van Eeden *et al.*, 2003; Zhou & Beck, 2007; Swart *et al.*, 2003).

The occurrence of sinkholes in MLM is historically associated with loss of life and damage to infrastructure. Some of the catastrophic events associated with the dewatering of dolomitic aquifers in the MLM area include the following:

- The sinking of West Driefontein crushing plant as well as the business sector of the Carletonville Township (known as Khutsong) into sinkholes;

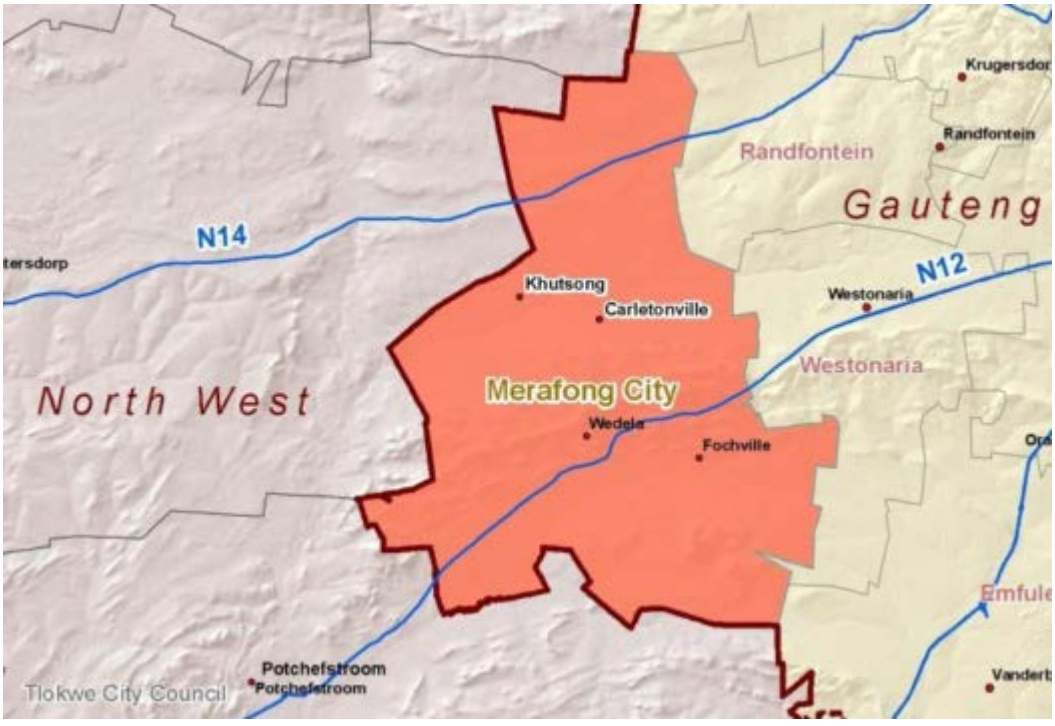

Figure 2: Geographic location of Merafong Local Municipality (Adopted from Kirshner (2011:27)

- Evacuation of inhabitants of the farm Bank due to unstable surfaces caused by ground movement;
- The death of a family of five at Blyvooruitzicht due to a sinkhole;
- Drying up of boreholes used for farming activities as well as cracking walls of local houses and the deterioration of infrastructure (Winde & Stoch, 2010; Van Eeden *et al.*, 2003; Van Eeden, 2006; Ngcobo, 2006; Swart *et al.*, 2003).

Given the extent of damage caused by sinkholes due to mining and human activities, the current study focuses on the causes and impacts of sinkholes, and also on possible strategies that can be adopted by the MLM City Council and its residents to reduce the risks associated with sinkholes. The sinkhole risk reduction strategy proposes a system that will eliminate or mitigate the occurrence of sinkholes by proactively monitoring and responding to aspects that lead to the formation of sinkholes.

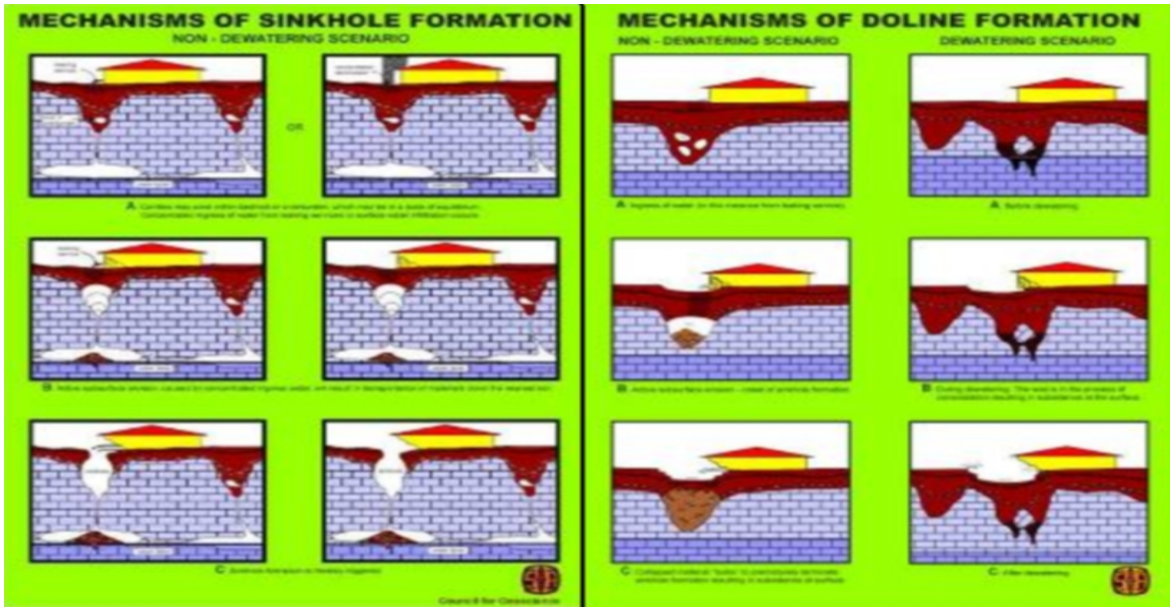

Figure 2: Mechanism of sinkhole formation (Adopted from Council of Geoscience, 2012)

1.2 Problem statement

The problem under investigation concerns the causes and effects of sinkholes on the economic developmentof communities in the MLM. The study is particularly focused on the loss of human lives and damage to property, as well as how these factors

increase the vulnerability of affected communities. The impact of these losses on the economic development of the area is also briefly explored. After the problem has been investigated, the study sets out to develop a strategy aimed at monitoring elements that contribute to the formation of sinkholes in the study area.

Twenty percent of the Pretoria-Witwatersrand-Vereeniging area of the Gauteng Province is underlain by dolomite (Buttrick & Van Schalkwyk, 1998; Swart *et al.*, 2003; Watermeyer, 2001; Ngcobo, 2006). This includes most of the gold mining areas in the Far West Rand where the study area is situated (Buttrick & Van Schalkwyk, 1998; Swart *et al.*, 2003; Watermeyer, 2001; Ngcobo, 2006). In order for mining operations to be executed successfully in a dolomite area, dolomitic compartments have to be drained with a view to ensuring the safety of workers (Van Eeden, 1997; Van Eeden, 2003; Swart *et al.*, 2003; Coetzee *et al.*, 2004).

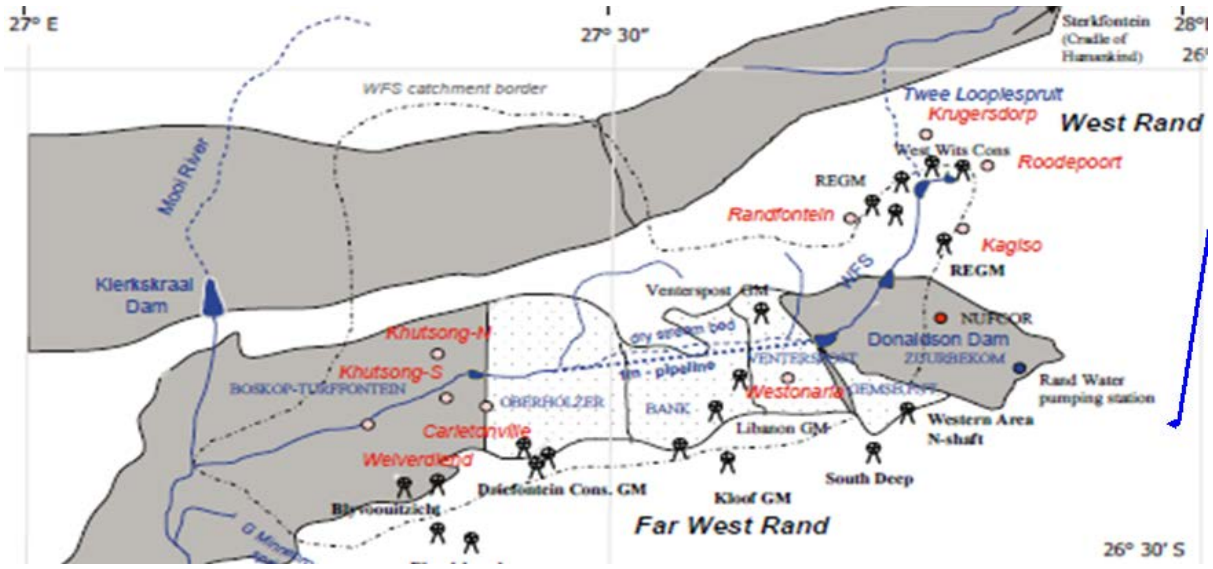

Figure 3: Mines within the Far West Rand (Adopted from Winde & Stoch, 2010:70)

The dewatering of dolomitic compartments for mining operations led to the lowering of water tables and excessive water seepage in a dolomitic area of Carletonville. As a result, the impacts of sinkholes started to become visible when the West Driefontein three-storey crusher plant disappeared into a sinkhole with twenty-nine occupants in 1962 (Van Eeden, 1997; Van Eeden, 2003; Swart *et al.*, 2003; Coetzee, 2004). On another occasion, the business sector of Khutsong Township (located near Carletonville) also collapsed into a sinkhole – resulting in financial

losses and property damage (Van Eeden *et al.*, 2003; Van Eeden, 2006; Ngcobo, 2006). In 1964, two houses and parts of other two houses disappeared into a sinkhole with the loss of five lives at Blyvooruitzicht mining village. Furthermore, the available statistics indicates that 35 people also died as a result of sinkholes (Van Eeden, 1997; Butrick & Schalkwyk, 1998; Swart *et al.*, 2003).

The occurrence of sinkholes did not only affect inhabitants and the surrounding properties, but also had a negative impact on the economic growth of the MLM. Examples include the deterioration of railway facilities at Bank farm due to the unstable ground surface, which consequently affected the transportation of goods to and from other towns and necessitated consumers to take their businesses to nearby towns (Van Eeden, 2003:118; Swart *et al.*, 2003; Watermeyer, 2001; Ngcobo, 2006). Moreover, a number of roads were also affected by occurrence of sinkholes. For instance, a portion of the P89/1 route to Pretoria in the Bank area was diverted, while danger signals on the P111/1 route to Johannesburg were installed. In 1963, parts of both roads – as well as some other district roads – were temporarily closed due to ground instability of the areas and the occurrence of sinkholes (Swart *et al.*, 2003; Ngcobo, 2006; Kirsten, *et al*., 2006; Van Eeden, *et al.*, 2007; Schoning, 1996; Wolmarans, 1996). Van Eeden (1997:116 - 122) further highlights a number of impacts on the local business sector associated with sinkholes. These included:

- *Disruption of town development*

Cracks and damage to buildings started to occur at an increased rate, and builders discovered subterranean caves during the construction work. These led to fewer buildings being erected (including business units). Houses were also demolished in Carletonville extensions no 5 and 8.

- *Agricultural setbacks*

  Farmers were advised to evacuate rich farming areas and a number of well - established businesses had to cease operating in the Bank area due to unstable surfaces caused by ground movement.

The establishment of gold mines and their expansion within the boundaries of MLM resulted in significant population growth due to the employment opportunities that were created by the mines (Van Eeden, 1997:106 -108). However, the continuation of mining activities always depends on the availability of gold in the mining area. In this regard, given the realities of retrenchments and the closure of a number of mines such as Deelkraal and Doornfontein, one can argue that – due to a lack of income and the consequent inability of people to pay for services – many ended up settling in the only areas they could find as a result of being financially and otherwise vulnerable (Van Eeden, 1997:122). However, as a result of reported sinkholes formation, one could argue that some of those areas were not suitable for human settlement. In this context, Van Eeden (1997:116) indicates several incidences caused by sinkholes which included loss of life (such as the death of the Oosthuizen family) as well as damage to infrastructure (like the sinking of Khutsong's business section). Therefore, the problem to be addressed is the occurrence of sinkholes and their impacts on the Merafong Local Municipality's community members. This will be achieved by investigating the factors contribute to the formation of sinkholes as well as explore ways to proactively manage those factors by means of a dolomite risk reduction strategy. The next section will describe the key research questions of the study.

1.3 Research questions

1.3.1 What are the causes of sinkholes in the MLM?

1.3.2 How do sinkholes affect the economic development of the community?

1.3.3 How does the local/district disaster management unit currently reduce or manage the risk of sinkholes in the MLM?

1.3.4 To what extent will proactive disaster risk planning and management contribute toward reducing the risks associated with sinkholes in the MLM?

1.3.5 How can the community participate in the process of mitigating the risk of sinkhole formation?

The subsequent section presents the research objectives.

1.4 Research objectives

A number of research objectives emanate from the above questions. These are:

1.4.1 To determine the main causes of sinkholes in order to establish a risk reduction or mitigation strategy.

1.4.2 To assess the impacts of sinkholes on the economic development of the community.

1.4.3 To evaluate how the local/district disaster management unit currently reduces or manages the risk of sinkholes in the MLM.

1.4.4 To determine the role of proactive disaster risk planning and management toward reducing the risks associated with sinkholes in the MLM.

1.4.5 To explore how the community can participate in the processes of mitigating the risks of sinkhole formation.

The next section outlines the theoretical argument of the study.

1.5 Theoretical arguments

The theoretical argument of the study is based on the priorities for action of disaster risk reduction as outlined by the Hyogo Framework for Action (HFA). The HFA is a global blueprint for disaster risk reduction that was adopted at the World Conference on Disaster Reduction held in Hyogo, Japan, in January 2005. It intends to systematically prevent and mitigate disaster risk in terms of losses in lives as well as social, economic and environmental assets of countries and communities (Olowu, 2010: 303 & Dlamini, 2011: 37). In order to develop disaster-resilient countries and communities, the HFA stipulates that the following five priorities for action must be implemented in the societies' disaster risk management units:

- *Making disaster risk reduction a priority*

  Ensuring that disaster risk reduction become a national and local priority with a strong institutional support for implementation.

- *Enhancing knowledge about the risk and taking action*

  The identification, assessment and monitoring of disaster risks and improvement of the early warning system.

- *Establish understanding and awareness*

  Use knowledge, innovation and education to establish a culture of safety and resilience at all levels.

- *Eliminate risk*

  Eliminate the underlying risk factors, and

- *Be prepared and ready to respond*

  Strengthen disaster preparedness for effective response strategy at all levels (ISDR, 2005; Dlamini, 2011).

The MLM should therefore ensure that an appropriate sinkhole risk reduction strategy is developed and incorporated into its current disaster risk reduction agenda for implementation. Furthermore, community members should be granted unlimited access to information about sinkholes and they should be informed about possible warning signs such as cracks on the walls as well as factors that may contribute to the formation of sinkholes (excessive water seepage). Armed with an increased understanding of the risks associated with sinkholes, inhabitants should therefore also be encouraged to report factors that contribute to the formation of sinkholes. These need to be monitored on a constant basis in order to proactively reduce the risk. The strategy for sinkhole risk reduction should not only focus on mitigating the risks, but should also focus on how to effectively respond to any adverse impacts caused by sinkholes. The next section presents specific aspects related to the research methodology of the study.

1.6 Research methodology

A qualitative research design was followed for this study, because it enabled the researcher to collect qualitative information in order to answer the research

questions (Crewell, 2003:250). Qualitative research is a process of studying a phenomenon in its full complexity, portraying its multi-faceted forms and trying to simplify what was studied or observed (Leedy & Ormrod, 2001; Struwig and Stread, 2007). It recognises that research takes place within a specific context and individuals are influenced by the environment in which they live. Thus the opinions of participants should not be seen in isolation but within the context of their environment (Blaikie, 2000: 233; Struwig and Stread, 2007: 71).

Qualitative research methodology has, amongst others, the following characteristics:

- It is able to provide a description of people's personal experiences regarding phenomena;
- It is able to describe complex phenomena;
- It describes the phenomena as they are situated and embedded in local context; and
- It is able to determine the cause of a social problem (Leedy & Ormrod, 2001; Struwig and Stread, 2007).

Thus, qualitative approach was selected for the study because it will enable the research, through the use of structured, unstructured and focus-group interviews, to gather:

- The views of MLM's community members regarding the formation and impacts of sinkholes;
- Information regarding the existence of mitigation and response strategies for the formation of sinkholes; and
- Information about the installation of water and sanitation facilities and how they were monitored and managed in order to avoid leakages.

1.6.1 Empirical investigation

This research required information regarding the strategies currently operationalised with a view of eliminating the risks associated with sinkholes. Therefore, semi-structured, unstructured and focus-group interviews were conducted (Bell, 2005:90). Semi-structured interviews enable the interviewer to tick responses on a pre-

prepared schedule, which allows the interviewer to leave the interview with a set of responses that can be easily recorded, summarised and analysed (Guthrie, 2010:119). Unstructured interviews enable the researcher to gain an in-depth understanding of the subject in a conversational form (Guthrie, 2010:119). This method is suitable for conducting an interview with an individual who can provide factual information regarding a specific topic (Bell, 2005:159; Creswell, 2003; Berg, 2006; Greener, 2011; Guthrie, 2010). Finally, focus-group interviews enabled the researcher to acquire individual and shared views regarding the impacts of sinkholes on the community as well as their views on possible measures to reduce the risk (Morgan, 1996; Langford & McDonough, 2003).

Semi-structured interviews will be conducted with officials of the Merafong Local Municipality's Water and Sanitation Department regarding the monitoring and maintenance of water and sanitation infrastructure. Furthermore, two unstructured interviews will be conducted. Firstly, an official in the disaster management department will be interviewed in order to gain in-depth information about the mitigation as well as response strategies for sinkhole formation. The unstructured interview will enable the researcher to gain an in-depth understanding, through the use of follow-up questions, about strategies used to manage the formation of sinkholes.

Secondly, unstructured interviews will be conducted with the ward councillors of sections that were affected by the occurrence of sinkholes, in order to obtain the views of the community on the impact of sinkholes and what they think should be done in order to solve the problem. Ward councillors are community members who have been elected by their communities to represent their concerns at the local authorities. Therefore, they serve as links between the community and the local authorities. Ward councillors will be interviewed because they work with community members on a daily basis and are therefore likely to be aware of the interests and concerns of the community. An unstructured interview will enable the researcher to gain in-depth information about the communities' perspectives of the occurrence of sinkholes and the associated effects. In support, focus group interviews will also be conducted with the community members to acquire individual and shared views

regarding the impact of sinkholes on the community as well as their views on possible measures to reduce the risk

1.6.2 Literature review

The review of pertinent literature can be regarded as the foundation of any research because it provides the researcher with information on what has been done, how it has been researched and what the key issues were (Booyens, 2008:27; Creswell, 2003; Berg, 2006; Greener, 2011; Mouton, 1996; Brazer, 2011). A literature study was used as the foundation for this investigation. The following sources were consulted in order to collect the relavent material for the purposes of this research:

- Catalogue of theses and desertions of South African Universities
- Catalogue of books: Merafong Library
- Catalogue of books: Tlokwe Library
- Catalogue of books: Ferdinand Postma Library
- Internet

1.7 Delimitation of the study

The outcomes of the study cannot be generalised to all areas where sinkholes occur. This study only focused on the impacts of lowered water tables in dolomitic compartments due to mining activities, as well as excessive water seepage in dolomite areas – and how these factors contribute to the formation of sinkholes. Finally, the study set out to determine how sinkholes affect the economic development of Merafong Local Municipality. The following section explains ethical considerations, after which the research structure is outlined.

1.8 Ethical considerations

Semi-structured, unstructured and focus-group interviews were conducted on a voluntary basis. Before the interview commenced, interviewees were informed that their participation was voluntary and that they could withdraw at any point during the interview. The confidentiality of all respondents was guaranteed. The research was

conducted in an environment that was safe and free from threats, and where the interviewees felt comfortable.

1.9 Structure of the research

Chapter 1 provides a brief overview of the research problem, the research methodology and discusses the tools used to address the research problem.

Chapter 2 presents an overview of the principles of the Hyogo Framework for Action as a tool for effective disaster reduction.

Chapter 3 focuses on South African laws in terms of disaster management as well as mining and environmental safety legislation

Chapter 4 offers an elaboration of other aspects related to the methodology that were adopted in the process of investigating the causes and impacts of sinkholes at MLM. In this chapter, issues relating to the qualitative research process, data collection methods, as well as the reliability and validity of research are discussed.

Chapter 5 outlines the findings of the study based on the objectives of the research. Themes based on the HFA priorities as indicated in the literature are used to analyse the results of the research in order to establish risk mitigation strategy for sinkholes.

Chapter 6 presents a summary of the findings of the research and provides recommendations aimed at assisting the municipality to address the challenge. The themes of the main findings are used as the basis for recommendations for future research. The following section provides a brief conclusion of the chapter.

1.10 Conclusion

Mines have played a leading role in terms of development within the boundaries of Merafong City Local Municipality (Van Eeden *et al.*, 2009; Jurad *et al.*, 2010:78–79; Winde & Stoch, 2010). Examples of these include the development of local infrastructure and the provision of labour – both of which boosted the local economy. However, the dewatering of the dolomitic compartments by mines has affected the

stability of the ground surface and has given rise to the formation of sinkholes. Sinkholes, in turn, have led to loss of lives and damage to infrastructure (Van Eeden *et al.*, 2009; Winde & Stoch, 2010). Damage to infrastructure (such as water pipes and sewage systems) increases surface water infiltration which, in turn, increases the probability of sinkhole formation (Van Eeden *et al.*, 2009; Jurad *et al.*, 2010:78–79; Winde & Stoch, 2010).

In this context, the aims of this research were to investigate the factors that contribute to the formation of sinkholes in the Merafong City Local Municipality, the impact of those factors on the economic developmentof the area, and finally to propose a strategy that could be adopted by Merafong Local Municipality and inhabitants in order to mitigate the possibility of sinkhole formation. The literature review as part of the research is presented in Chapter Two.

Chapter 2

International Policies that shaped Disaster Risk Reduction

2.1 Introduction

In the previous chapter, the history regarding the impacts of sinkholes on the economic development of the MLM was discussed in detail. This chapter will briefly discuss the international policies that shaped the development of disaster risk reduction and present an in-depth discussion of the Hyogo Framework for Action as the theoretical argument of the study as well as the data analysis tool. In this light, Blaikie *et al.* (1994:233), indicate that towards the beginning of the 1970s, the terms disaster prevention, preparedness and mitigation were used more frequently and often interchangeably. This was mostly because during this period (1970s) several major disasters, such as the north Peruvian earthquake, the Sahel drought and famine of 1973/4, and the Tangshan earthquake claimed the lives of hundreds of thousands of people. This was followed by even more tumultuous and deadly 1980s; with the Bhopal chemical plant accident in India in 1984; the Armenian earthquake in 1988 (55 000 lives lost); Ethiopian famine in 1984/5; the Somali war, and the Exxon Valdes oil spill of 1989. Together, these events led the international community to

reconsider the manner in which disasters should be managed in future (Rosenthal, Comfort & Boin, 2001: 319; Van Niekerk, 2005:46; Von Oelreich, 2011). The scientific community and professional groups (NGO's, development agencies, donor countries, etc.) in particular realised that there had to be a more effective method of responding to disasters than only providing relief materials to the survivors (Rosenthal, Comfort & Boin, 2001: 320; Comfort *et al.*, 1999; Von Oelreich, 2011). The events mentioned above intensified the drive towards the development of a better global system for disaster preparedness, because a realisation had grown that the relief mechanism was not effective in reducing the impacts of disasters. Consequently, the international humanitarian community was motivated to develop a more comprehensive strategy that entailed functions of preparedness, prevention, mitigation, reconstruction and rehabilitation as an alternative to disaster relief approach (Comfort *et al.*, 1999; Von Oelreich, 2011). In this context, Van Niekerk (2005: 47) argues that the use of the term 'disaster mitigation' signified a new paradigm shift towards disaster risk reduction and also expanded on the ideas of disaster preparedness and management.

As a way forward, the General Assembly in 1971 requested the Secretary-General of the United Nation (under resolution 2816 xxxvi) to appoint an Emergency Relief Coordinator to assist with the cases of natural disasters (Von Oelreich, 2011). During this period the focus was placed on relief, warning systems, stockpiling and others such as pre-disaster planning (Von Oelreich, 2011, Van Niekerk, 2005). In 1974, the General Assembly, under resolution 3345 (xxix), requested a multidisciplinary research body to investigate the relationship between population, resources, environment and development with the intention to improve the strategies for coping with disasters in the context of social and economic development. In 1987 the General Assembly referred to the report of the World Commission on Environment and Development, which recommended that a different approach should be adopted in dealing with hazards that affects the environment. Therefore, the inadequacies of the international relief system to address continuous losses due to disasters brought with it the realisation that alternative interventions were needed (Lechat, 1990: 2; Von Oelreich, 2011). To address some of those inadequacies, on 22 December 1989 the General Assembly of the United Nations designated the period from 1990

to 1999 as the International Decade for Natural Disaster Reduction (IDNDR) (IDNDR) (WMO, 1997: 1; Smith, 2002: 348; UNISDR, 2002: 17; Lechat; 1990; 2; Van Niekerk, 2005: 53; UN, 1989).

2.2 The International Decade for Natural Disaster Reduction (IDNDR)

In December 1989, the United Nation General Assembly adopted Resolution 44/236 which proclaimed the year 1990 - 1999 as the International Decade for Natural Disaster Reduction (IDNDR) (WMO, 1997: 1; Smith, 2002: 348; UNISDR, 2002: 17; Lechat; 1990; 2; Van Niekerk, 2005: 53; UN, 1989). During this decade the international goal was to ensure a shift in reactive approach towards natural disasters to that of pro-active planning and prevention (Housner, 1989:45-46; Lechat, 1990:2; Smith, 2002: 348). Specifically, the IDNDR envisaged that all countries would, by the year 2000, have conducted national risk assessments, developed national and or local preparedness plans, and implemented global, regional, national and local warning systems (UNESCO in Van Niekerk, 2005:54). The IDNDR had the following five main goals:

- To enhance the ability of each country to alleviate the impacts of disasters, assist developing countries to assess the potential damage that might be caused by disasters, as well as establishing early warning systems and disaster-resistant buildings where necessary;
- To establish guidelines and strategies to utilise scientific and technical information, as well as considering the cultural and economic diversity of different countries;
- Adopt scientific and engineering endeavours aimed at gathering information about the hazards in order to minimise the loss of life and damage to properties;
- Distribute new and existing information regarding measures to assess, forecast, and lessen the effects of disasters; and
- Establish measures to assess, forecast and lessen the effects of disasters through programmes that provide technical support and transfer technology

as well as provide education and training for specific disasters and societies, and to assess the efficiency of those programmes (UN, 1987; Smith, 2002: 348, UN, 1989).

The IDNDR and its goals were initially influenced by scientific and technical considerations, but the global interest in the economic and social impact of disaster only developed as the decade progressed (Bades *et al.*, 1991: 288-289). Blaike *et al.* (1994, xiv) indicate that the emphasis that the IDNDR placed on scientific solutions, as well as the transfer of hazard-mitigation technologies to developing countries was mostly capital intensive and did not take the capacities of those countries into consideration. The IDNDR was also criticised by Bates *et al.* (1991:288-289) for not considering the social, political and economic dimensions of disasters. They further indicated that it was no longer adequate to focus only on structural and technical solutions to hazards. The IDNDR also failed to expand the concept of hazard reduction to include technological hazards induced by human development, ii) recognise the importance of including risk-reduction initiatives in sustainable development programmes, iii) violated human rights in disasters, iv) a low degree of relief coordination and collaboration, and v) difficulty in providing aid (Smith, 2002: 349; McEntire, 1997: 225; Rosenthal, Comfort and Boin, 2001). Some of the weaknesses were also depicted during the mid-decade review and at the end of the decade it was acknowledged that the 10-year period allocated was not sufficient to address all the challenges identified in the international arena (Van Niekerk, 2005: 56). Another significant event which influenced the agenda of disaster risk reduction was the World Conference on Natural Disaster Reduction held in Yokohama, Japan, from 23 – 27 May 1994, and the subsequent adoption of the Yokohama Strategy and Plan of Action for a Safer World (UNISDR, 2002: 18).

2.2.1 The Yokohama Strategy and Plan of Action for a Safer World

The Yokohama Strategy and Plan of Action for a Safer World was articulated in 1994, but its principles were more relevant in the twenty-first century than when they were conceived (UNISDR, 2002: 18). Van Niekerk (2005: 58) indicates that those principles provided the platform upon which most conceptualisation in terms of disaster risk reduction of the new millennium was based.

The Yokohama Strategy and Plan of Action for a Safer World (1994) emphasised that each country is obliged to safeguard its citizens from the impacts of disasters and that priority must be given to developing countries. It further stressed the importance of developing and strengthening national capacities and capabilities, and where necessary, national legislation for disaster prevention, mitigation and preparedness, including the mobilisation of NGOs and involvement of local communities. Finally, the strategy also emphasised the significance of promoting and strengthening sub-regional, regional and international cooperation in prevention, reduction and mitigation of disasters.

The Strategy was grounded in the perception that disasters continued to strike and escalate in magnitude and frequency, but the phenomenon causing them were mostly beyond human control (UNISDR, 2002:18; Yokohama Strategy and Plan of Action for a Safer World, 1994). Therefore, it was crucial that societies must strengthen their indigenous methods and consider new ways to live with risk, and react appropriately to prevent as well as lessen the impacts of disaster (UNISDR, 2002:18; Yokohama Strategy and Plan of Action for a Safer World, 1994). During the process of reviewing the progress made in implementing the Yokohama Strategy, challenges to systematically address disaster risk reduction in the context of sustainable development were identified. The review emphasised the importance of pro-active approaches to inform, motivate and involve people in all aspects of disaster risk reduction in their local communities in order to exploit the existing resources and establish practices for more effective disaster reduction (Schipper & Pelling, 2006). The IDNDR was followed by the International Strategy for Disaster Reduction (ISDR) in 2000.

2.2.2 The International Strategy for Disaster Reduction

The International Strategy for Disaster Reduction (ISDR), as the descendent of the IDNDR, emphasised the importance of protection against hazards, reducing vulnerability and building resilient communities (UNISDR, 2002:19). Its goals were firstly, to establish a multi-disciplinary approach towards disaster reduction within the broader context of sustainable development; secondly, to increase public awareness to understand risk, vulnerability and disaster reduction globally; and thirdly, to ensure

political commitment to the development and implementation of disaster reduction policies and actions by all governments, but in particular those mostly exposed to the impacts of hazards (UN/ISDR, 2004, Van Niekerk, 2005: 60; Stanganelli, 2008).

To ensure that the objectives of the ISDR would be reached, the Inter-Agency Secretariat for the ISDR (UN/ISDR) was established as a focal point by the United Nation General Assembly through its resolutions 54/219 (UN, 2000a) and 56/195 (UN, 2002). The UN/ISDR was able to bring different stakeholders from different sectors together through the Inter-Agency Task Force on Disaster Reduction (AITF/DR). The AITF/DR, as the principal body for the development of disaster reduction policy, established four working groups to focus on climate and disasters, early warning, risk, vulnerability and impact assessment (UNISDR, 2004). Furthermore, the Task Force indicated that it would also focus on additional areas such as ecosystem management, exploring public-private partnerships, raising the political profile of disaster reduction, land-use planning, and integrating issues of disaster reduction into developmental planning (UNISDR, 2004). The ISDR served as the organising body for the second World Conference on Disaster Reduction (WCDR).

2.2.3 The World Conference on Disaster Reduction

In December 2003, the UN General Assembly adopted resolution 58/214, in which it decided to convene the second World Conference on Disaster Reduction (WCDR) (the first conference took place in Yokohama, Japan, in 1994 and adopted a plan of action called the Yokohama Strategy). The second conference took place in Kobe, Japan, in 2005 (Van Niekerk, 2005: 61). The WCDR adopted a Hyogo Declaration, and the Hyogo Framework for Action 2005 - 2015: Building the Resilience of Nations and Communities to Disasters, which aimed at defining a plan of action for 2005 - 2015 (UN, 2003). The second WCDR had the following five objectives:

- To conclude and report on the review of the Yokohama Strategy and its Plan of Action, with a view to update the guiding framework on disaster reduction for the twenty-first century;

- To identify specific activities aimed at ensuring the implementation of relevant provisions of the Johannesburg Plan of lmplementation of the World Summit on Sustainable Development on vulnerability, risk assessment and disaster management;
- To share good practices and lessons learned to further disaster reduction within the context of attaining sustainable development, and to identify gaps and challenges;
- To increase awareness of the importance of disaster reduction policies, thereby facilitating and promoting the implementation of those policies; and
- To increase the reliability and availability of appropriate disaster-related information to the public and disaster management agencies in all regions, as set out in relevant provisions of the Johannesburg Plan of lmplementation of the World Summit on Sustainable Development (UN, 2005:8).

Among others, the Conference addressed disaster reduction challenges relating to the following thematic areas:

- Governance: Institutional and policy framework for risk reduction;
- Risk identification, assessment, monitoring and early warning;
- Knowledge management and education;
- Reducing underlying risk factors;
- Preparedness for effective response and recovery.

The review of the progress made in implementing the Yokohama Strategy during the second WCDR, identified challenges to develop systematic actions in order to address disaster risk in the context of sustainable development. The identified challenges were then used as a foundation to develop a framework for action for decade 2005 - 2015 (Van Niekerk, 2005; Sorensen *et al.*, 2006: 27 Stanganelli, 2008: 92). The section to follow will discuss the Hyogo Framework for Action as the theoretical argument of the study in greater detail.

2.3 Hyogo Framework for Action (HFA) inception

The HFA was conceived in January 2005, when over 4000 representatives from private sectors, NGOs, academic institutions, and governments gathered in Kobe, Japan, at the second World Conference on Disaster Reduction (UN/ISDR, 2005: 1; Von Oelreich, 2011; Bhatt: 2007). At this conference, governments adopted a 10-year plan to reduce the impacts of both natural and man-induced hazards. They adopted the Hyogo Framework for action as guideline to mitigate the impacts of disasters on human lives (deaths and injuries) as well as on economic, social and environmental assets of countries and societies (Walker: 2005, HFA: 2010, Bhatt: 2007; UN/ISDR, 2005: 1). The HFA focuses on disasters that are caused by environmental as well as technological hazards. It promotes the integration of disaster risk reduction into developmental policies, planning and programming for establishment and strengthening of institutions, mechanisms and capacities to improve resilience to hazards and for incorporation of risk-reduction initiatives into preparedness, response and recovery programmes (UN/ISDR, 2005: 1; Von Oelreich, 2011; Bhatt: 2007).

The adoption of the HFA by the WCDR and its support by the General Assembly of the UN (Resolution 60/1952) followed a process which started in 1990 with the declaration of the IDNDR (ISDR, 2004:13). In 1994 the IDNDR adopted the Yokohama Strategy, which attributed the importance of disaster risk analysis and emphasised the role that people can play in order to reduce the vulnerability of communities to disasters. At the end of the period allocated for the Yokohama Strategy, the UNISDR carried out the review which identified challenges in the following areas: governance, risk identification and assessment, monitoring and disseminating early warning messages, information management and education, reducing the underlying risk factors, and effective response and recovery. The review outcomes were submitted to the WCDR and formed the foundation for the formulation of the HFA (ISDR, 2004:13).

The HFA emphasises Disaster Risk Reduction (DRR) rather than responding to disasters (UN/ISDR, 2005: 3; Walker: 2005; HFA: 2010; Bhatt: 2007). DRR is a framework which intends to systematically prevent and lessen disaster risks with

regard to losses in lives and the socio-economic assets of countries and communities (UN/ISDR, 2005: 3; Walker: 2005; HFA: 2010; Bhatt: 2007). It takes into account the inputs of various stakeholders (government, civil society organisations, academic institutions, etc.), and it also outlines the basic concepts and prescribes the expected outcomes by assigning tasks to various actors at different operational levels (UN/ISDR, 2005: 2; Walker: 2005; HFA: 2010). DRR, as conceptualised in the HFA, has the following three strategic goals:

- More effective integration of disaster risk considerations into sustainable development policies, planning and programming at all levels, with a special emphasis on disaster prevention, mitigation, preparedness and vulnerability reduction;
- The development and strengthening of institutions, mechanisms and capacities at all levels, especially at the community level, that can systematically contribute to building resilience to hazards;
- The incorporation of risk-reduction approaches into the design and implementation of emergency preparedness, response and recovery programmes in the reconstruction of affected communities (UN/ISDR, 2005: 3-4 Walker: 2005, HFA: 2010, Bhatt: 2007).

Drawing from the conclusions of the review of the Yokohama Strategy and on the basis of discussions of the WCDR and expected outcome and strategic goals of the Conference, five priorities for action were adopted. The following section will present an in-depth discussion of the five HFA priorities for action. It will also briefly highlight the global as well as South African progress in terms of implementing the HFA as outlined by the View of the Frontline (VFL) reports.

2.3.1 Priority for action 1 - Ensuring that DRR is a national and local priority with a strong institutional basis for implementation

Natural and human-induced hazards damage infrastructure and essential facilities which in turn results in loss of lives, economic and environmental disruption. They also affect development programmes by reducing assets and interrupting the planning process (UN, 2004). In this context, the state is primarily responsible for

protecting people, infrastructure, economic and social assets from the impacts of hazards (UN/ISDR, 2004:29; UN, 2004; Van Niekerk & Botha, 2013: 2). This implies that the state has the responsibility to provide a proper and effective institutional framework and capacity for DRR. However, this can only be achieved when there is political commitment which translates into, the development of policies, strategies and structures which are supported by operational legislative frameworks (UN/ISDR, 2007:07; UN, 2004).

Amongst others, formulation of legislation serves as a proof of political commitment and government's intention to develop policies and programmes in order to support and coordinate disaster risk reduction activities (Chagutah, 2009:115; UN, 2004; Poolman, 2011: 27; Kadzatsa, 2011: 48). Legislation plays a pivotal role in defining the institutional arrangements and roles as well as ensuring compliance in the implementation of policy and resource allocation. It ensures that all levels of disaster risk management structures receives full benefit of its support and it also provides a framework for accountability and the enforcement of regulations relating to disaster risk management (Chagutah, 2009:115; UN, 2004; Poolman, 2011: 27). Policies consist of decisions that steer the actions of government (Chagutah, 2009:115; UN, 2004; Poolman, 2011: 27; Kadzatsa, 2011: 48). For instance, disaster risk reduction policies may address issues relating to the understanding of hazards, assessment of vulnerability, risk evaluation and the adoption of risk reduction measures. Disaster risk reduction initiatives tend to be more effective if they are incorporated into the country's developmental policy and goals (Chagutah, 2009:115; UN, 2004; Poolman, 2011: 27; Kadzatsa, 2011: 48).

Resilience towards disasters can be strengthened by mainstreaming disaster risk reduction activities into development policies and programmes. Mainstreaming refers to the process of modifying a specific type of work in order to accommodate contextual changes as well as act directly upon them (Mitchell, 2003: 2; la Trobe, 2005; Wamsler, 2006: 152; Suntanta *et al.*, 2006: 342; Poolman, 2011). Therefore, legislation provides framework and authority for the implementation of strategies that seek to incorporate disaster risk reduction into developmental programmes by defining the rights and responsibilities as well as implementation, enforcement and accountability mechanisms (Mitchell, 2003; la Trobe, 2005; Wamsler, 2006). The

South African Disaster Management Act (57 of 2002) is an appropriate example of this, amongst others, it emphasises the importance of integrating disaster management into the developmental plans of local municipalities through the integrated development plans (IDPs) in order to address disaster risk effectively (Van Niekerk, 2006; Hoogstad & Kruger, 2008).

Although all levels of government are obligated to protect its citizens from the impacts of natural and human-induced hazards, it is of upmost importance to discuss the role of local government because they interact with the communities on a regular basis (Burby *et al.* 2007). Since disasters occur at local level, local government becomes automatically responsible for engaging in a pro-active disaster risk reduction initiatives as well as providing relief to victims (Burby *et al.* 2007). In this regard, the decentralisation of authority for decision making and resource allocation is essential to ensure that effective approaches are implemented to manage disasters and programmes take into account the community`s social, cultural, environmental as well as economic aspects. Decentralisation of authority will also grant local governments the authority to manage their budgets in accordance with the initiatives that are associated with risk reduction (Visser and Van Niekerk, 2009; Doreth *et al.*, 2011). For instance, staff members can be continuously trained to equip them with necessary skills to implement risk reduction initiatives. However, in practice there are budgetary constraints or “red tape” in accessing financial resources and in most cases officials are also not skilled to effectively implement disaster risk reduction strategies (Van Niekerk and Coetzee, 2012; Visser and Van Niekerk, 2009; Doreth *et al.*, 2011).

The role of local government in institutionalising disaster risk reduction is vital because it is the unit where practical activities such as land use practices can be regulated and safer construction methods can be promoted and enforced (Ahrens &Rudolph, 2006; Burby *et al.* 2007; Suntanta *et al.* 2006). For instance, in the case of Merafong Local Municipality (MLM), it is the responsibility of local authorities to ensure that the erection of low income houses takes place in inhabitable areas and that the installation and monitoring of water and sanitation facilities receives priority to reduce the possibilities of sinkhole formation.

Before discussing the global as well as South African progress with regards to the implementation of the HFA, it is essential to briefly discuss the tool that is used to measure such progress. After the adoption of the HFA in 2005, the Global Network for Disaster Reduction (GNDR) was formed to support the implementation of the HFA (Botha & Van Niekerk, 2013: 1). The GNDR developed a project called View from the Frontline (VFL) to measure the progress of HFA implementation at national and local level. The project is undertaken every two years and data is collected by means of a survey (quantitatively) and as a part of the survey, participants are also given the opportunity to comment (qualitative) (Botha & Van Niekerk, 2013: 1). In this light, the mid-term review report (2010 - 2011) on the implementation of the HFA reflected that several countries have established national legislation on disaster risk management in the mid-1990s and since then there have been an increasing number of countries that has updated their legislations in accordance with the HFA principles. However, some of the new laws relating to agriculture, water resource management, and green energy – as a means to address disaster risk – were not incorporated with the existing legislative frameworks; consequently, this has direct bearing on how effectively disaster risk can be managed (UN/ISDR, 2011:22 - 23).

The escalating number of National Platforms across the world is an indication of the pressure created by the HFA towards an increased need for a multi-stakeholder approach to risk reduction (UN/ISDR, 2011). The number of National Platforms increased from 38 in 2007 to 73 in 2011. In August 2006, 63 governments had committed themselves to designate focal points to implement the HFA (UN/ISDR, 2011:22 – 23). Furthermore, the number of focal points was reported to have increased to 192 in 2011(UN/ISDR, 2011:22 – 23). In terms of the implementation of disaster risk reduction policies and decentralisation of authority to local level, South Africa obtained an average score of 1.9 out of 5. Furthermore, with regard to the decentralisation of budget, an average score of 2.2 was obtained. In terms of funding, an average score of 2.3 was achieved (Botha and Van Niekerk, 2013:7). The score obtained by South Africa for the implementation of disaster risk reduction policy and decentralisation of authority to the local government reflects that little progress was made. And there is still a lot of work to be done in this regard. In addition, the scores obtained for decentralising the budget and funding disaster risk

reduction activities reflects that significant progress was achieved but there is definitely a room for improvement, especially at local government level.

2.3.2 Priority for action 2 - Identify, assess and monitor disaster risks and enhance early warnings

The first step in reducing disaster risk is to identify the hazard and understand its nature, causes, severity as well as the kind of damage it does (Carreno *et al.*, 2007; Perez-Lugo; 2001; Forbes-Biggs, 2011:11). Knowledge about hazards and vulnerability can be utilised to set priorities with regard to early warning systems. An early warning system refers to a set of capabilities needed to develop and distribute warning information to allow individuals and communities faced by hazards to act in advance in order to reduce the possibility of harm or loss (Basher, 2006: 2168; Perez-Lugo; 2001). However, the role of risk assessment should be considered before early warning systems are discussed in depth, because information about risk is required to develop warning messages (Basher, 2006: 2168).

Risk assessment refers to systematic procedures that determine the nature and extent of hazards by analysing it and evaluate the conditions of vulnerability that can adversely affect people, property, livelihood and the environment (Basher, 2006: 2168; Perez-Lugo; 2001; Poolman, 2011: 12; Forbes-Biggs, 2011: 13). It starts by identifying natural or human-made hazards that have the potential to affect a society. By identifying and assessing potentially calamitous events, risk assessment provides governments and involved stakeholders with the basis for prioritising resources for disaster risk reduction, improving emergency management systems, and tailor their mitigation strategies in a manner that suits the needs and preferences of the local communities (Perez-Lugo, 2001; Carreno *et al*., 2007). A comprehensive risk assessment is the one that considers different types of calamitous events and their underlying drivers as well as recognises the importance of indigenous knowledge (Basher, 2006: 2168; Perez-Lugo, 2001; Carreno *et al.*, 2007; Poolman, 2011: 13). Indigenous knowledge is a crucial part of any risk assessment because communities are knowledgeable on types of disasters that occur in their environment and are able to anticipate them in some cases (Basher, 2006: 2168; Perez-Lugo, 2001; Carreno *et al.*, 2007; Poolman, 2011: 13).

Risk assessment can be based on historical experience as well as current social, economic and environmental vulnerability. However, regardless of the methodology used, three steps must be undertaken before starting the process of risk analysis (Van Niekerk, 2006: 103; APELL, 2010: 14; Poolman, 2011: 12; Forbes-Biggs, 2011: 13).

Firstly, the system to be studied and the objectives of the risk analysis should be defined. An analysis can be conducted for reasons such as the identification of new hazards, assessing the efficiency of risk control strategies, or identifying additional measures to control the risk. To increase the usefulness of the information obtained through analysis, it is important to understand how the information will be used and which hazards were included and excluded during the analysis.

Secondly, the amount and type of data to be collected for performing a sound analysis will be influenced by the objectives of the analysis, but it will also include information on the technical, natural or social environment being studied and the identification of possible hazards (APELL, 2010: 14; Basher, 2006; Thomalla, 2006).

Finally, the methodology for analysis must be selected, based on the objectives of risk analysis as well as the amount of data available (UN/ISDR, 2007: 6; Van Niekerk, 2006: 103; APELL, 2010: 14). In the case of MLM, continuous sinkhole risk assessment is crucial because it will contribute to the understanding of risk factors and risk information can be used to develop effective strategies to mitigate the impacts of sinkholes.

Risk assessment requires a continuous monitoring of hazardous events, particularly those that are dynamic in nature (Basher, 2006: 2168; Perez-Lugo; 2001; Poolman, 2011: 12; Forbes-Biggs, 2011: 13). This will assist in supporting regular reviews and re-assessment of hazards, exposures and vulnerability as well as improving the understanding of evolving risk landscape and risk knowledge as a result of new data. In order to reduce the impacts of disasters, people should be well-informed about the nature of hazards and measures they can adopt to minimise their vulnerability (Basher, 2006: 2168; Perez-Lugo; 2001; Poolman, 2011: 12; Forbes-Biggs, 2011: 13).

In this light, the information acquired via risk assessment can be used in public awareness programmes with the intention of changing behaviours so that communities can be more resilient to hazards (Chagutah, 2009: 116; Poolman, 2011: 12; Forbes-Biggs, 2011: 13). Information on hazards and vulnerability should be communicated in a manner that the targeted group will understand and, if possible, it should be accompanied by practical actions that can be adopted to reduce the risk as well as the expected benefits of those actions (Chagutah, 2009: 116; Poolman, 2011:12).

As mentioned above, knowledge about hazards and vulnerability is vital to setting priorities regarding early warning systems as well as guiding the preparation of response activities. An early warning system is an element of disaster risk reduction that focuses on identifying the hazard and disseminating warnings with the intention of saving lives during a disastrous event (Sakai *et al.*, 1999: 5; UN, 2004; Poolman, 2011: 21). Effective early warning system must be established in an understandable manner and it must be relevant to the community which they serve (Sakai *et al.*, 1999: 5; UN, 2004; Poolman, 2011: 21; Kadzatsa, 2011: 53).

A complete and effective community-based early warning system consists of four, inter-connected elements: (i) risk knowledge, (ii) monitoring and warning service, (iii) dissemination and communication service, and (iv) response capability (*see Figure 3*) (Phaiju *et al.*, 2910: 29; Basher, 2006: 2168; Kadzatsa, 2011: 53). A failure in any of these elements could result in the redundancy of the whole warning system (Phaiju *et al.*, 2910: 29; Basher, 2006: 2168; Kadzatsa, 2011: 53). The purpose of a community-based early warning system is to empower those who are threatened by hazards to act appropriately in order to reduce the probability of personal injury, loss of life, and damage to property as well as the environment (Phaiju *et al.*, 2910: 29; Basher, 2006: 2168; Kadzatsa, 2011: 53).

The mid-term review report on implementing the HFA indicated that, in 2007, few countries had reported (through the submission of annual reports) on conducting effective risk assessments, and even lesser reported on using risk information to develop disaster risk reduction policies, strategies, and plans. However, in 2009 an increased number of reports were received for conducting risk assessments, but

they reflected that challenges were encountered in conducting assessments that could inform policies, link warning systems with preparedness and response, as well as guiding the local level contingency plan (UN/ISDR, 2011 :23-24; VFL, 2009).

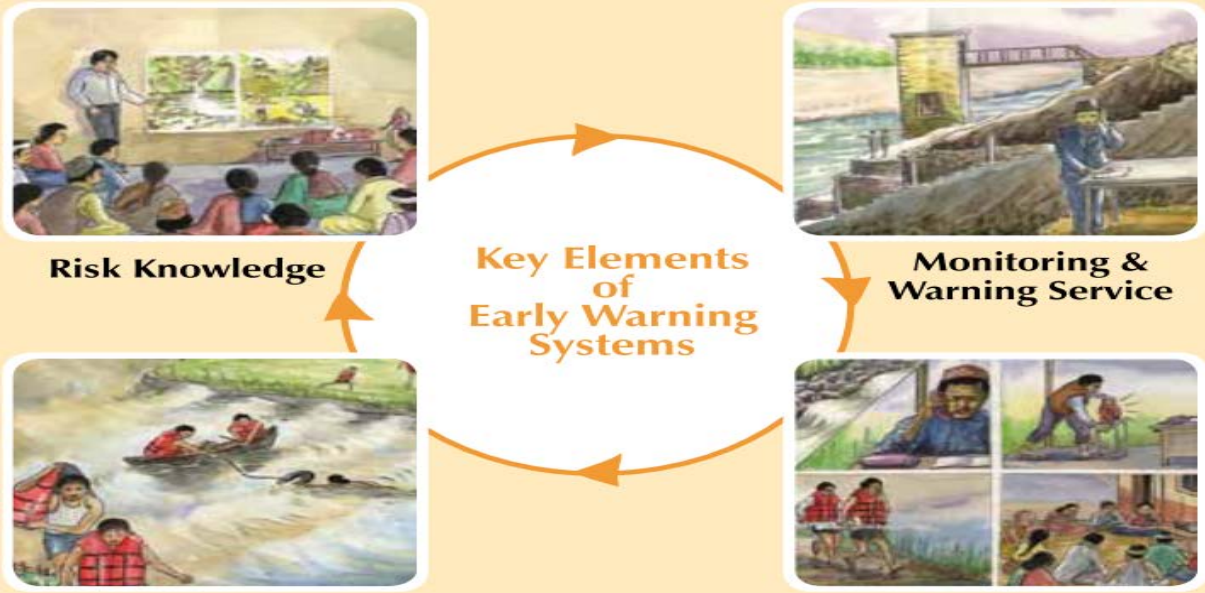

Figure 3, **Community-based warning system (**Adopted from Phaiju *et al.*, 2010:29)

A world-wide survey on early warning systems, conducted by the ISDR in 2006, discovered that while some warning systems were effective, most of the developing countries experienced challenges in terms of disseminating information to those at risk (UN/ISDR, 2011:23 – 24; VFL, 2009). But in 2007, several countries reported progress in developing warning systems (UN/ISDR, 2011:23 – 24; VFL, 2009). It is essential to indicate that the 2011 VFL results contrast with the 2011 GAR national level results, which revealed improvement in the 2009 - 2011 reporting cycle (VFL, 2011:21). Therefore, it is evident that the progress at national level does not translate into effective implementation of disaster risk reduction at local level (VFL, 2011:21). This is further supported by the research conducted by Botha and Van Niekerk (2013:7) which indicates that South Africa obtained an average score of 1.7 for gathering risk information and 1.8 for disseminating the information to societies at-risk. Furthermore, 1.8 was also achieved for the monitoring of disaster reduction activities. The scores obtained for gathering risk information, disseminating it, and monitoring disaster risk reduction activities reflects that minimal efforts have been made in this regard. This reflects a definite room for improvement.

2.3.3 Priority for action 3 - Use knowledge, innovation and education to build a culture of safety and resilience at all levels

According to Patel and Izadkhah (2008) the crux of developing a disaster resilient society is heavily influenced by the success of disaster reduction education. Formal and informal education can be used to distribute information and increase understanding about disaster risks, teach preparedness as well as demonstrate possible ways to react during disasters (UNESCO, 2005; Burby *et al.*, 2007: 256; Clerveaux & Spence, 2009: 209). Building a disaster resilient community through formal education entails, amongst others, the incorporation of disaster reduction curriculum or lessons in schools and post-school institutions because it is believed that children and young people are more receptive to new information and they can also act as a good channel to transfer knowledge to their families (Burby *et al.*, 2007: 256; Clerveaux & Spence, 2009: 209). Another reason for including risk reduction lessons in schools is to equip children, as the future generation, with information because disasters can be reduced if people are well-informed about the measures they can take to reduce the vulnerability (UNESCO, 2005; Burby *et al.*, 2007: 256; Clerveaux & Spence, 2009: 209).

Informal education (transmitting information outside the standard of a school setting) can also be used to broaden the knowledge of people who are already familiar with various risk reduction skills that they have acquired over a period of time through experience as well as community practices (Mercer *et al.*, 2009; Rambau *et al.* 2012). Informal education can be presented in various ways that seek to introduce and reinforce important risk reduction knowledge, skills and competencies (Mercer *et al.*, 2009; Rambau *et al.* 2012; UNESCO, 2005; Pearce, 2002; Izadkhan & Hosseini, 2005; Clerveaux & Spence, 2009: 221). Amongst others, the following methods can be used:

- Creative educational materials: using documentaries, short videos and computer games to transmit awareness and knowledge;

- Cultural and performing arts: using art forms such as poetry, dance, songs, etc. to transmit risk reduction knowledge to parents in an informal setting or during special events;

- Disaster drills: performing simple drills to practice what to do during a disastrous event;

- Dissemination of written materials: using posters to share risk reduction information; and

- Contact sessions with students, parents and local government: this will contribute to the identification of hazards, tapping into indigenous knowledge, sharing scientific research and expertise to assess the risk and identify the solutions (Mercer *et al.*, 2009; Rambau *et al.* 2012; UNESCO, 2005; Pearce, 2002; Izadkhan & Hosseini, 2005; Clerveaux & Spence, 2009: 221).

Cuba is an example of how formal and informal education can be used to increase resilience. It has incorporated disaster preparedness, prevention and response as part of their school curricula because of its exposure to hurricanes. The information that children learn at school is supported by training courses and drilling for parents as well as by radio and television programmes (Wisner, 2006: 14).

The VFL mid-term report revealed that, out of 27 countries that reported on the HFA in 2007, the majority indicated progress in terms of developing and integrating disaster reduction into school-based programmes as well as distributing information to the public. However, the average global progress (as indicated by the 2009 View from the Frontline Report) in implementing most areas of this priority was considered weak (figure 4), more especially in terms of the development and application of multi-risk assessments as well as developing nationwide public awareness campaigns to promote a culture of disaster resilience (UN/ISDR, 2011:24; VFL, 2009).

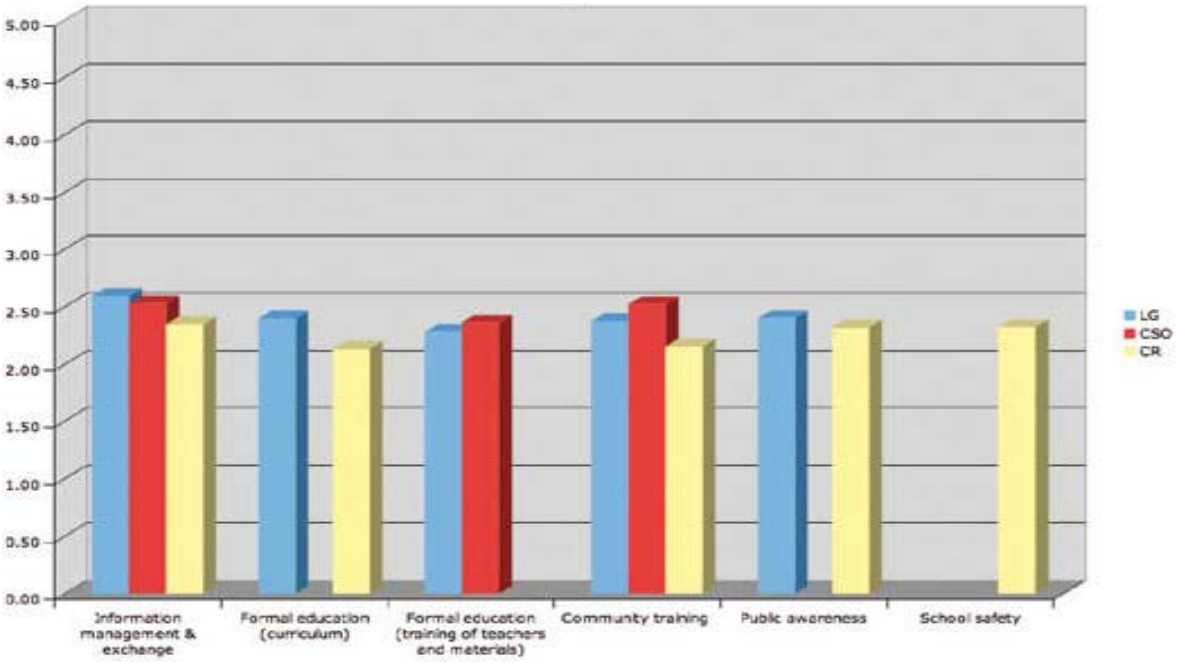

Figure 4, **Views on priority for action 3: Knowledge and Education** (Adopted from the Global VFL, 2009:23)

The 2011 VFL report revealed that there seemed to have been very little progress over the two-year period from 2009 to 2011. These findings were in line with the research conducted by Van Niekerk & Botha (2013) which revealed that South Africa obtained an average score of 1.9 for integrating indigenous knowledge into disaster prevention activities. An average score of 1.7 was obtained in terms of training provided for public officials and community members involved in disaster prevention. The importance of training cannot be underestimated as risk reduction initiatives can be effectively implemented if people are aware of the risks they are facing.

2.3.4 Priority for action 4 - Reduce the underlying risk factors

In developing countries disasters cause serious setbacks to economic and social development. For instance, the reconstruction costs of repairing damage to water, sanitation, energy, telecommunication, roads and railway infrastructure – caused by flooding in Mozambique in 2000 – was estimated to be US$ 165.3 million (Mirza, 2003:240). This example shows how disasters result in the destruction of fixed assets and physical capital, interruption of production and trade, as well as diversion

and depletion of savings. For developed countries, the levels of economic losses are higher as a result of the higher density and cost of infrastructure as well as production level, but less developed countries suffer higher levels of loss when perceived as a proportion of Gross Domestic Product (GDP) (UNDP, 2004: 20; Stromber, 2007; Mirza, 2003). In 1998, Hurricane Mitch caused losses and damages in Honduras equals to a shocking 44% of the GDP (Stromberg, 2007; Mirza, 2003). This has long-term effects and may erode the development capacity and weaken the coping and survival skills of communities (Stromberg, 2007; Mirza, 2003).

In this light, disaster risks relating to changing social, economic, environmental conditions, land use, and the impact of hazards associated with geological events, weather, water, climate variability and climate change can be addressed during sector development planning and programmes as well as in post-disaster situations (Sakai *et al.*, 1999; UN, 2004). Before discussing the measures to address the underlying risk factors, it is essential to briefly describe the causes of disaster risk. The Pressure and Release (PAR) model argues that disaster risk result when the hazard interacts with the condition of vulnerability (Sakai *et al.*, 1999; UN, 2004). It further argues that the root causes of risk result from an interconnected set of general processes (societal structures, political and economic activities) that occur within a community (see figure 5). These general processes translate their effects into unsafe conditions (risk), which determine the extent of vulnerability when interacting with a hazard at a specific location. Therefore, risk can be reduced by addressing factors (societal structures, political and economic activities) that cause pressure on societies, or by tackling the conditions of vulnerability (Gaillard, 2010; Cardona, 2003; Birkmann, 2006; Cannon, 1994).

Thus, to reduce the underlying risk factors, structural and non-structural prevention as well as mitigation measures must be implemented. This means to anticipate potential sources of risk by putting into practice procedures and other measures to either avoid hazard or reduce the economic, social and environmental impacts through corrective interventions (Carreno *et al.*, 2006; Sutanta *et al.* 2006: 344; UN, 2004). Risk assessment should be used as a tool to determine the nature and extent of risk by analysing potential hazards and evaluating existing conditions of vulnerability that could pose a potential threat or harm to people, property, the

environment, and the livelihoods on which they depend. Subsequent planning can be used to design and implement activities that aim to reduce the risk because the impacts of hazards can be increased by unplanned or inadequate human activities such as development in a hazard prone area as well as inadequate safety measures (Carreno *et al.*, 2006; Sutanta *et al.* 2006: 344; UN, 2004). Effective planning and land use management, for instance, can be used to regulate the use of land and natural resources in a safe manner.

Land use management refers to all the activities that are associated with regulating the use of land and natural resources (Sutanta *et al.* 2006: 245; Sakai, 1999). It ensures that proper management rights, restrictions and risk related to property, land and natural resources are adhered to since vulnerability can be exacerbated by factors such as: (i) settling in hazard-prone areas (such as highly dolomitic areas) (ii) weakening the capacity of the environment to withstand hazards by destroying forests and wetlands or dewatering dolomitic compartments, (iii) building houses as well as public facilities which are unable to withstand the impacts of hazards, and (v) lacking social and financial safety mechanisms (Joyce, 2011; Sutanta *et al.* 2006). Land use planning and management can be used as a tool for regulating the use of land and to enforce standards and codes for buildings and other structures (Sakai, 1999; Blaikie *et al.*, 1994; Wisner *et al.*, 2004; Joyce, 2011; Sutanta *et al.* 2006: 245). The effectiveness of this can be manifested in the case of rapid urbanisation where housing demands exceed the capacity of local authorities to provide formal houses – land use management can be used to restrict the erection of informal settlements in hazardous zones such as hillsides that are prone to slippage, faulty zones (sinkhole-prone areas), and vulnerable flood plains (Sutanta *et al.*, 2006: 342).

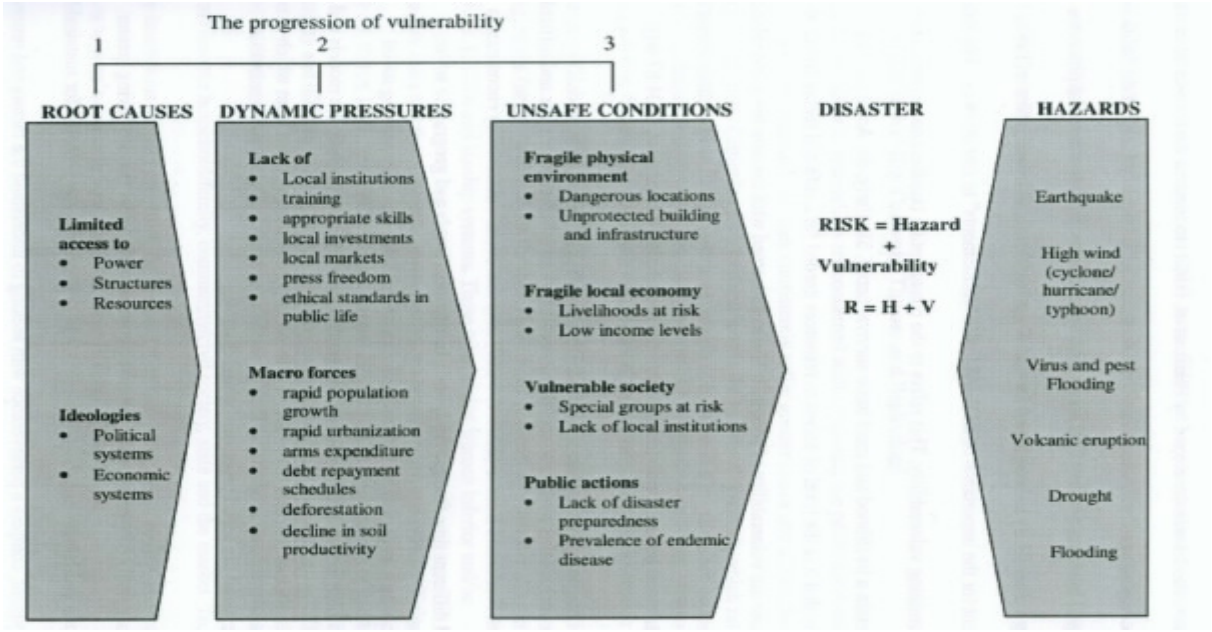

Figure **5 Pressure and Release (PAR) model: The progression of vulnerability** (Adopted from Gaillard, 2010)

In light of the above, a top-down approach to reduce vulnerability to disasters has become unsuccessful in addressing the needs of vulnerable communities. Therefore, it is essential to adopt an approach that will involve those who are vulnerable in the planning and implementation of mitigation measures (Ahrens & Rudolph, 2006; Rambau *et al.*, 2012; Lunga, 2008). A comprehensive assessment of a community's exposure to hazards and analysis of their vulnerabilities and capacities serve as foundation for planning projects and programmes that can reduce disaster risk (Lunga, 2008: 20; UN, 2004:187; Rambau *et al.*, 2012; Chagutah, 2009: 118; Ahrens & Rudolph, 2006). In this context it is clear that vulnerability can be perceived as a key factor that determines the extent of risk (Basher, 2006; Mirza, 2003; Bosher 2011). Thus, the ability to measure vulnerability is a vital step towards effective risk reduction and promoting a culture of disaster resilience. Furthermore, the underlying vulnerabilities can be reduced by strengthening existing programmes such as the use and management of ecosystems and natural resources (Basher, 2006; Mirza, 2003; Bosher 2011).

The 2007 VFL report on the implementation of HFA reflected that very few countries had developed measures to reducing the underlying risk factors. Furthermore, the report also revealed that very little was mentioned about reducing the risk through sustainable use of natural resource as well as integrating risk reduction measures

into environmental management (UN/ISDR, 2011:27- 28; VFL, 2009). The reporting cycle, ending in 2009, reflected that several countries experienced challenges to address the risk factors, such as poor urban and local governance, vulnerable rural livelihoods, and ecosystems that lost the capacity to withstand the impacts of hazards (see figure 6). This challenge was further amplified by the initial data for the 2009 - 2011 progress report, which showed that only 28% of the reported countries rated their progress between 4 and 5 for addressing the underlying risk factors (UN/ISDR, 2011: 28). The reports also indicated that governance arrangements for disaster risk reduction did not facilitate the integration of risk considerations into development (UN/ISDR, 2011:27- 28; VFL, 2009). However, lower and middle income countries reported most progress with regard to mainstreaming disaster risk reduction into their development plans, climate change, and poverty reduction policies. Nonetheless, little progress was reported in terms of integrating risk reduction measures into strategies that address the underlying drivers of risk (UN/ISDR, 2011:27- 28).

When assessed for reducing the underlying risk factors, South Africa obtained an average score of 2 regarding the availability of action plans at local level and the involvement of at-risk communities in disaster reduction initiatives (Van Niekerk & Botha, 2013). As indicated earlier, the allocated budget did not cover risk reduction projects; thus reducing the underlying risk factors remains a challenge, especially at local government level (Van Niekerk & Botha, 2013).

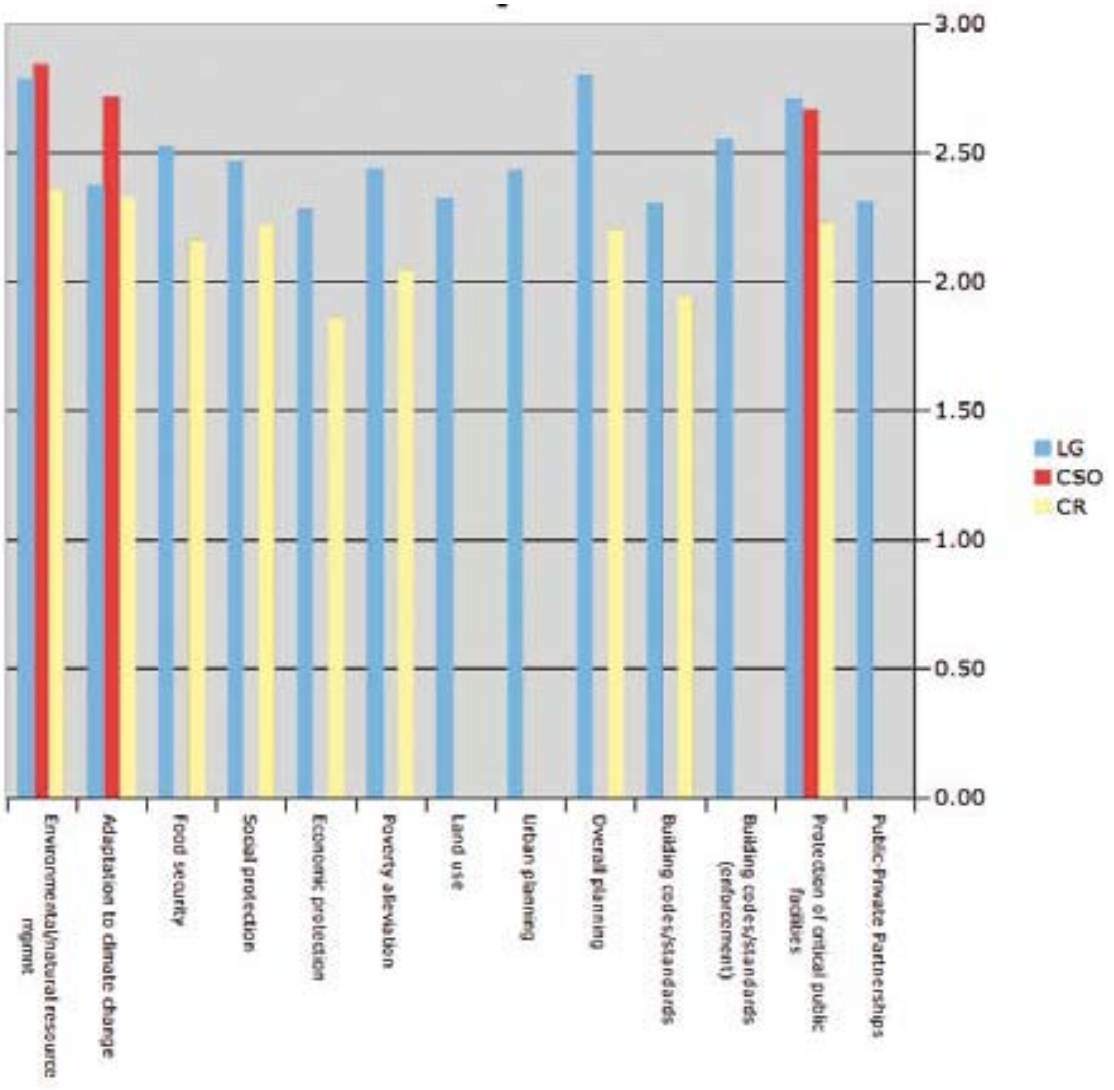

Figure 6, Views on priority for action: 4 Underlying risk factors (Adopted from the Global VFL, 2009:26).

2.3.5 Priority for action 5 - Strengthening disaster preparedness for effective response at all levels

No matter how well a country or community plans to prevent disasters, there will always be a chance of disaster striking (Tierney *et al.*, 2001; Christoplos, 2001; Joyce, 2011; Chagutah, 2009). This implies that not all natural hazards can be prevented from occurring, but their impact can be reduced by equipping communities with the knowledge and capacity to be prepared or to respond and manage disasters effectively. In this light, the fundamental aim of preparedness planning is to strengthen the capacity to respond to different hazardous situations that might affect

a community by implementing a set of preparedness measures. Preparedness measures include early warning systems, on-going risk and vulnerability assessment, capacity building, the creation and maintenance of stand-by capacities, as well as reserving necessary resources (UN/ISDR, 2006:15; UN/ISDR, 2008: 20; Tierney *et al.*, 2001; Christoplos, 2001; Joyce, 2011; Chagutah, 2009). Contingency planning, as an element of the preparedness plan, serves as a vital component in developing an analysis of what needs to be done and it also helps when designing, testing and implementing response actions (UN/ISDR, 2008: 21; Tierney *et al.*, 2001; Christoplos, 2001; Chagutah, 2009).

Contingency planning is used as a tool to analyse the impact of potential hazardous events so that adequate and appropriate arrangements can be developed in advance to respond effectively and appropriately to the needs of the affected community (UN/ISDR, 2008: 21; Tierney *et al.*, 2001; Christoplos, 2001, Kadzatsa, 2011: 55). If based on a sound analysis of risk in a specific context, it will reflect the nature of the hazards or threats as well as the vulnerabilities and capacities in that particular situation (UN/ISDR, 2008: 21; Tierney *et al.*, 2001; Christoplos, 2001, Kadzatsa, 2011: 55). Information should be collected through a detailed vulnerability mapping exercise to identify specific areas and communities at risk. The plan should include information on how the affected community and key stakeholders will get information. Furthermore, provision should be made for updated information and local knowledge to feed back into the government system enabling people affected by disasters to express their views and share the lesson learned. The plan also needs to be tested and exercised by the people as well as organisations that will use it (UN/ISDR, 2008: 22; Joyce, 2011; Tierney *et al.*, 2001; Allen, 2006; Kadzatsa, 2011: 56).

Building preparedness capacity requires an assessment of the systems in place and available resources. Capacity assessments can reveal hidden assets and available resources that can be built upon to strengthen preparedness and lead to a more predictable and efficient response and recovery process (Allen, 2006; Kadzatsa, 2011; Tierney *et al.*, 2001). It should consider available resources, existing capacities, operational plans and procedures, as well as communication and coordination systems at every level to identify gaps and capacity-building

requirements in order to plan accordingly (Tierney *et al.*, 2001; Joyce, 2011; Allen, 2006; Kadzatsa, 2011: 54). Capacity-building activities should include measures to analyse responses to previous disasters and to incorporate lessons learned into future capacity-building strategies. The lessons learned can also be used as part of the warning alert to minimise the impact of disasters (UN/ISDR, 2008: 24).

Warning alerts allow the public and emergency response teams to take preventative action to avoid harm (UN/ISDR, 2008: 24). Warning messages should incorporate an understanding of the values, concerns and interests of those who will need to take action. Furthermore, warning systems must be tested to make sure that messages are well understood and that systems function effectively (UN/ISDR, 2008: 27; Basher, 2006; UN, 2004: 66). Public education and awareness-raising prior to any disaster can also be used as a platform to provide information on hazards, vulnerabilities, risks, and how to reduce the impact of disaster on vulnerable communities. They can also be used to enlighten the community on how warnings will be disseminated and on how to respond to different types of hazards after an early warning message has been issued (UN/ISDR, 2008: 27; UN, 2004: 237).

Effective emergency stand-by capacity is also a critical component of a preparedness system (UN, 2004; Basher, 2006). Stand-by capacity should include monitoring systems as well as human, physical and logistics resources. A representative from organisations that took part in the contingency planning should also participate in a stand-by roster for rapid deployment in case of an emergency (UN, 2004; Basher, 2006). These teams should exist not only at national, but also at regional and local levels as well. And they should have immediate access to basic resources (such as satellite phones, vehicles, and support services) that may be necessary for response (UN/ISDR, 2008:32).

The VFL reports on the implementation of HFA that were submitted for the 2007 reporting cycle indicated that governments had achieved the most success in implementing this Priority for Action (UN/ISDR, 2011:30). An example of this was reflected by the reduced mortality rate as a result of weather-related hazards in developed and developing countries. In support of this, the data submitted for 2009-2011 revealed that 80% of the reported countries had measures (contingency plans)

in place to deal with disasters. However, the allocation of finances to manage responses at local level remained uneven (UN/ISDR, 2011:30).

South Africa obtained an average score of 2.1 when assessed for the level of expertise to implement risk reduction initiatives (Van Niekerk & Botha, 2013). In this context, effective response to disasters requires the ability to identify the hazards, assess the risks, and develop contingency plans. This implies that without adequate expertise to conduct risk assessments, and develop warning systems as well as contingency plans to strengthen disaster resilience, communities will most probably suffer immensely from the impacts of hazards (Joyce, 2011; Allen, 2006; Kadzatsa, 2011: 54). It can be argued that South Africa has a lot of work to do towards creating a culture of safety by means of contingency planning and simulation exercises.

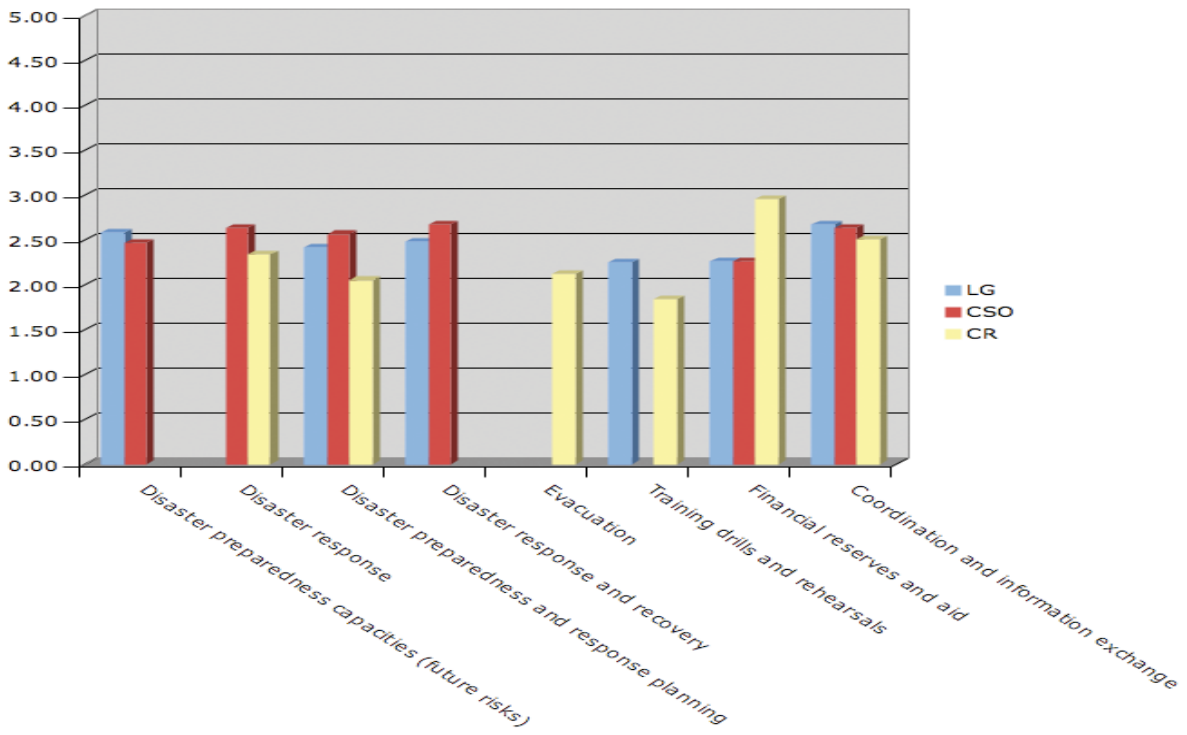

Figure 7, Views on priority for action: 5 Disaster preparedness and response (Adopted from the Global VFL, 2009:28)

2.4 Conclusion

The aim of this chapter was to discuss the HFA in detail. It indicated that the International Decade of Natural Disaster Reduction (1990-1999) was the first policy

to be implemented to reduce the impacts of disasters and its goal was to shift from a reactive approach to a more proactive planning and prevention methods. However, the International Decade of Natural Disaster Reduction failed because, amongst other reasons, it placed too much emphasis on scientific solutions and it also failed to expand the concept of hazard reduction to include man-induced technological hazards. As a descendent of the International Decade of Natural Disaster Reduction, the International Strategy for Disaster Reduction (adopted in 2000) emphasised the importance of reducing vulnerability and building resilient communities. Its goals were to i) establish a multi-disciplinary approach towards disaster reduction within the broader context of sustainable development, ii) increase public awareness to understand risk, vulnerability and disaster reduction globally iii) ensure political commitment to the development and implementation of disaster reduction policies. In December 2003, the United Nation General Assembly decided to convene the second World Conference in Disaster Reduction in Kobe, Japan. During this conference, the Hyogo Framework for Action (HFA) was adopted for the decade 2005-2015.

The fundamental purpose of the HFA was to assist the nations in their efforts and endeavours to build resilient cities and enable communities to cope with hazards that threaten their developmental gain. It emphasises Disaster Risk Reduction (DRR) rather than disaster response. DRR is a framework which intends to systematically prevent (avoid) and mitigate (lessen) disaster risks with regard to losses in lives and the socio-economic assets of communities and countries. In order to systematically prevent and mitigate disaster risk, the HFA stipulates the following five priorities of action to be implemented by governments: (i) insure that DRR is a national and local priority with a strong institutional basis for implementation; (ii) identify, assess and monitor disaster risk and enhance early warning; (iii) use knowledge, innovation and education to build a culture of safety and resilience at all levels; (iv) reduce the underlying risk factors; and (v) strengthen disaster preparedness for effective response at all levels.

The HFA is an appropriate framework to be applied in managing the formation and impacts of sinkholes in the MLM because it stipulates that risk reduction activities should be prioritised by the local authorities such as city councils. This means that

local government should take a leading role in ensuring that risks are identified (the formation of sinkholes) and monitored, and that warning messages are issued to the community when necessary. The framework also ensures that community members are informed about the factors that can exacerbate the formation of sinkholes in order to create awareness and build a culture of safety as well as to reduce the underlying risk factors. The framework also recognises that no matter how hard the MLM tries to reduce the risk of sinkhole formation, they should be prepared to act because hazards cannot be completely stopped from occurring. The following chapter will discuss the legislative framework of the study.

Chapter 3

Managing sinkhole risk: a review of disaster management, mining and environmental management legislation

3.1 Introduction

This chapter focuses on South African disaster management legislation that guides the implementation of disaster risk management activities as well as mining and environmental management laws that regulate the activities of mining operations which might have detrimental impacts on the environment and increase the vulnerability of communities to hazards such as sinkholes. Firstly, it provides a comprehensive discussion on the key performance areas (KPAs) as well as the second enabler, as depicted by the National Disaster Management Framework Policy, in order to highlight the statutory requirements for the implementation of disaster risk management in South Africa. Specifically, the following KPAs will be discussed: integrated institutional arrangement (KPA 1); disaster risk assessment (KPA 2); disaster risk reduction (KPA 3); response and recovery (KPA 4) as well as the second enabler, namely Education, Training, Public Awareness and Research. This will be followed by the discussion on environmental and mining laws that have to be taken into account in formulating a sinkhole risk reduction strategy.

3.2 Development of disaster management legislation in South Africa

According to Van Niekerk (2006: 96), South Africa did not have a comprehensive approach to deal with disasters before 1994. Disasters were simply perceived as unavoidable natural acts that could not be projected or prevented, as a result the focus was primarily on response and recovery. But after the United Nations declared the period from 1990 to 2000 as a decade to reduce the impacts of natural disasters, all member states were encouraged to revisit their disaster management approaches to ensure that disaster prevention, mitigation and preparedness were prioritised. As a member state, South Africa dedicated itself to develop an approach that was in line

with the international practice of managing disasters (Vermaak & Van Niekerk, 2004; Munzelele, 2011: 36). As a result, the government established an Inter-Ministerial Committee for Disaster Management in 1997, which was responsible for developing disaster management legislation in South Africa. In the beginning of year 2000, the South African Disaster Management Bill was availed for public discussion and in January 2003 the new Disaster Management Act (57 of 2002) (hereafter referred to as the Disaster Management Act) was promulgated (Van Niekerk, 2005 & 2006; Pelling & Holloway, 2006; Ngcamu, 2011; Reid & Van Niekerk, 2008). Apart from the Disaster Management Act, South Africa also has a National Disaster Management Framework (NDMF) which steers the development and implementation of disaster management approaches (Ngcamu, 2011: 122). For the purpose of this study, the NDMF as well as its KPAs and enablers were used as a guideline for the development and the implementation of sinkhole risk reduction strategies for MLM. The following section provides a comprehensive discussion of the framework

3.3 National Disaster Management Framework

The National Disaster Management Framework (NDMF) is divided into four Key Performance Areas (KPAs) – which are guided by the objectives set out in the Disaster Management Act – and three enablers which are crucial for the successful implementation of the KPAs (Botha *et al.*, 2011; Van Niekerk, 2005 & 2006; South Africa, 2005: 2). In line with the HFA's priorities for action (discussed in chapter 2) (also see table 3.1), the first KPA oversees the existence of an integrated institutional capacity for disaster risk management in all government spheres (national, provincial and local). The second KPA deals with issues relating to conducting disaster risk assessment in order to steer initiatives, while the third KPA deals with issues relating to disaster risk management planning in order to reduce disaster risks. Finally, KPA 4 deals with issues relating to effective response and recovery from the impacts of disasters.

Alignment between the HFA's priority for action and the KPAs	
HFA's priority for action	**KPAs**

Priority for action 1 Ensuring that DRR is a national and local priority with a strong institutional basis for implementation	KPA 1 Integrated institutional arrangement Enabler 3 (Funding arrangements for disaster risk management)
Priority Action 2 Identify, assess and monitor disaster risks and enhance early warning	KPA 2 Disaster risk assessment and monitoring
Priority Action 3 Use knowledge, innovation and education	Enabler 2 (Education, Training, Public Awareness) Enabler 1 (Information Management and Communication)
Priority Action 4 Reduce the underlying risk factors	KPA 3 Disaster Risk Reduction
Priority Action 5 Strengthen disaster preparedness for effective response at all levels	KPA 4 Response and recovery

Table 3.1 (Alignment between the HFA's priority for action and the KPAs)

The three enablers ensure the successful implementation of the KPAs: the first enabler focuses on the establishment of information and communication system, while the second enabler deals with aspects relating to education, training, public awareness and research (South Africa, 2004; Van Niekerk, 2011). The last enabler focuses on arranging funding for disaster risk management. It is essential to note that for the purpose of this study only the second enabler will be discussed, as the aim is to develop a strategy for sinkhole risk reduction for the MLM. As a result education, training, public awareness and research forms key components of such a strategy. The subsequent section will provide an in-depth discussion of the first KPA.

3.3.1 KPA 1: Integrated Institutional Capacity for Disaster Risk Management

The fundamental objective of KPA 1 is to establish institutional structures to support the implementation of disaster risk reduction initiatives in all spheres of government (national, provincial and local) (South Africa, 2004; Van Niekerk, 2011, Ngcamu,

2011). The NDMF indicates that the Disaster Management Act is prescriptive about the structures that should be established at national, provincial and local government (South Africa, 2004). The structures at national, provincial, and local levels will be discussed will be discussed below.

In light of the above, section 4 of the Disaster Management Act indicates that the National Disaster Management Centre (NDMC) has the highest administrative authority in South Africa and is responsible for the establishment of institutional structures that will guide and facilitate the development and implementation of effective disaster risk management (South Africa, 2003). In other words, the NDMC serves as a main unit to ensure the functionality of disaster risk management at the national level. It is responsible for developing the disaster management policy and legislation, provide guidance for their implementation as well as steer and monitor the multidisciplinary disaster risk management initiatives amongst various spheres of government (South Africa, 2005b:2). In addition, the NDMF – as aligned to the Disaster Management Act, section 15(1–4) and 21, requires the NDMC to execute the following functions:

- Create and sustain the institutional structures that will support the execution of the provisions outlined by the Act;
- Execute the activities that will support the development of a progressive disaster risk profile to guide planning and implementation of disaster risk reduction measures;
- Assess progress with regard to the updating of disaster risk management plans and strategies by government spheres involved in disaster risk management;
- Ensure the development and implementation of disaster risk management strategies that will result in resilience towards disasters;
- Ensure that disaster risk reduction initiatives are incorporated into developmental plans;
- Guide the development of response and recovery plans to ensure effective response to hazards that could lead to disaster, and to mitigate the impact of unpreventable disasters;

- Support the provincial and municipal disaster management centres in executing awareness campaigns in order to enhance disaster resilience.
- Assist with the development of an effective information management and communication system;
- Conduct performance assessments to determine the effectiveness of disaster risk reduction initiatives;
- Monitor the provincial and municipal disaster management centres in terms of their compliance with the Act (especially sections 21, 56 and 57) as well as the Key Performance Indicators stipulated by the NDMF; and
- Make recommendations for funding disaster risk reduction initiatives and oversee that the funds are made available for disaster risk management (South Africa, 2003).

3.3.1.1 Disaster Risk Management structures in the national government sphere

In order for the NDMC to achieve the abovementioned objectives, the NDMF – in line with the Disaster Management Act – requires that the Inter-governmental Committee on Disaster Management (ICDM) should be established in all spheres of government to advise on issues relating to disaster risk management (South Africa, 2005a:8; South Africa, 2003:10). The ICDM is a structure established by the President and it consists of representatives from all three spheres of government. It is primarily responsible for advising the Cabinet on issues relating to disaster risk management and to guide ministers on the development of the NDMF. Furthermore, it serves as a platform upon which different political representatives deliberate on disaster risk management issues (South Africa, 2005a:8; South Africa, 2003:10). The purpose of involving the political dimension in disaster risk management is to optimise the possibility of disaster risk management policy and projects to be successfully implemented. This is because in South Africa, political will often determines the success or failure of societal programmes (Pelling & Holloway, 2006:09; Ivanova *et al.*: 2001; Dollar & Svensson: 2000). In order to ensure that various organisations partake in disaster risk management, section 5 of the Disaster Management Act calls

for the establishment of the National Disaster Management Advisory Forum (NDMAF).

The NDRMAF is a structure in which national, provincial, and local government, as well as other organisations involved in disaster risk management, consult and coordinate their strategic actions (South Africa, 2005). In addition, this structure must also provide advises (on disaster risk reduction) to different spheres of government, the private sector, community-based organisations (CBOs), and non-governmental organisations (NGOs). The NDMF indicates that the NDMAF has a role to play in each of the following:

- Drafting of disaster management plans;
- Promotion of joint standards of practice;
- Development of disaster management information system;
- Assist with effective communication channels;
- Making recommendations on training and advising on public awareness campaigns;
- Reviewing of programmes and policy (South Africa, 2005:15).

The NDMF calls for the establishment of the National Interdepartmental Committee on Disaster Risk Management (NICDRM). The NICDRM is a non-statutory structure which is established to facilitate the interaction between different state departments at all levels of government (Van Riet & Diedericks, 2009:5). It is a platform where different government departments coordinate and integrate their disaster risk management administrative activities. Furthermore, this structure also makes provision for technocrats to compile disaster-related plans and strategies, and also serves as an accountability platform between the different departments (Van Riet & Diedericks, 2009:5; Van Niekerk, 2005:139). The establishment of disaster risk management structures is further cascaded from national to provincial level. To ensure continuation from the national level, the NDMF in-line with the Disaster Management Act mandates the provinces to establish structures that are established at national level in order to support the implementation of disaster risk management plans and strategies at provincial level.

3.3.1.2 Disaster Risk Management structures in the provincial government sphere

The NDMF (South Africa, 2005: 12) indicates that in order to ensure integrated disaster management at provincial level, the provincial governments should establish and co-ordinating structures which are similar to the structures that exist at national level. In this light, provinces are responsible for co-ordinating and facilitating the implementation of disaster management policy at provincial level. In order to ensure that the policy and programmes are implemented at provincial level there has to be political support. The Premier's Intergovernmental Forum provides a platform where the premier of each province consults with the MECs (Members of the Executive Council) and other decision makers in the province. The Premier's Intergovernmental Forum is a consultative body that consists of the premier, a member from the executive council of the province (responsible for local government), the mayors of district and/or metropolitan municipalities in the province, and a representative of organised local government in the province. In line with the structure at national level, the MEC responsible for the implementation of disaster risk management may constitute a Provincial Disaster Risk Management Advisory Forum (PDRMAF).

The PDRMAF is a platform where provincial government and disaster risk management officials in the province consult each other and co-ordinate their provincial disaster risk management initiatives (South Africa, 2005a:34; Van Niekerk, 2006:107). It consists of the head of the Provincial Disaster Management Centre, a senior representative of each department designated by the premier, the heads of municipal disaster risk management centres in the province, representatives from organised local government in the province, as well as members of other disaster risk management role-players (i.e. academic institutions). It is essential to indicate that the establishment of the PDRMAF is not a statutory requirement (Ngcamu, 2011: 125). However, should the province decide not to establish the PDRMAF, it should ensure the establishment of an appropriate alternative structure for the purpose of disaster risk management advisory issues. Furthermore, the provinces are also required to develop and implement their disaster risk management

framework. In order to ensure consistency with the Disaster Management Act and NDMF, the Provincial Disaster Risk Management Framework (PDRMF) should consist of the four KPAs and three enablers tailored according to the provincial needs (South Africa, 2005a; Van Niekerk, 2006). For the implementation of the PDRMF, the province should establish institutional support, which is the Provincial Disaster Management Centre.

In terms of section 1.2.4 of the NDMF, the MECs responsible for disaster risk reduction should establish the institutional capacity for the implementation of disaster risk reduction in each province. This implies that the provinces should establish the Provincial Disaster Risk Management Centres (PDMC) as stipulated in Chapter 4 of the Disaster Management Act. It is of critical importance to indicate that the mandate of the PDRMCs is similar to that of the NDRMC, but it is limited to the provincial boundaries. Furthermore, PDRMC should establish a link between the objectives outlined by the NDRMC and the municipal disaster risk reduction initiatives. It should also support the municipal disaster risk management centres as and when the need arises (South Africa, 2005a:34; Van Niekerk, 2006:107).

Another structure that can (not a statutory requirement) be established at provincial level is the Provincial Interdepartmental Committee on Disaster Risk Management (PICDRM) (Van Niekerk, 2005). This structure consists of senior provincial staff members of each province as well as members with relevant technical expertise within the province. The PICDRM has functions and responsibilities similar to that of the NIDRMC, except that the PICDRM functions within the provincial boundaries (Van Niekerk, 2005). The structures that are established at provincial level should also be established at the municipal level for the sake of consistency with national and provincial disaster risk management practices.

3.3.1.3 Disaster Risk Management structures in the local government sphere

The role of local government in institutionalising disaster risk reduction is vital because it is the unit where practical activities such as risk reduction and land use management can be regulated and safer construction methods can be promoted and enforced (Ahrens &Rudolph, 2006; Burby *et al.* 2007; Suntanta *et al.* 2006). The

establishment of disaster risk management structures at local level is essential to ensure that strategies, policies and projects are implemented in such a way that the impacts of hazards can be reduced in order to establish disaster-resilient communities. For instance, the establishment of disaster risk management structures at the MLM will ensure that when policies and strategies are developed, they take into consideration issues such as the risks caused by sinkholes, as well as invite various stakeholders (including community members) to serve on committees such as the Municipal Disaster Risk Management Advisory Forums. The establishment of disaster risk management structures and the involvement of stakeholders will create a platform for exchanging ideas and allocate responsibilities accordingly. In the case of the MLM, the establishment of disaster risk management structures and the involvement of relevant stakeholders will ensure that community members report the possible signs of sinkhole formation as well as leakages. This, in turn, will enable municipal officials to improve their response to such hazards as well as assist them in planning and mitigate the risk. The Disaster Management Act and NDMF indicate that the municipal council for each metropolitan and district municipality should establish the institutional structures to implement disaster risk management in their areas.

Section 43 of the Disaster Management Act requires each metropolitan and district municipality to establish disaster risk management centres in its area of jurisdiction to support the implementation of local, provincial and national disaster risk management strategic policies (South Africa, 2003). The district municipality should establish disaster management centre after consultation with the local municipalities in its area. And such a centre can be operated in partnership with the local municipalities. It is essential to indicate that the Municipal Disaster Management Centre (MDMC) should specialise in disaster risk issues that exist in its area and emphasises prevention as well as mitigation of disaster risks by promoting formal and informal risk avoidance practices by government departments, non-governmental organisations and community-based organisations (South Africa, 2003; Van Niekerk, 2005).

Section 43 of the Disaster Management Act further indicates that district municipalities should consult with the local municipalities regarding the establishment and management of disaster risk management structures, including disaster management centres, frameworks, and advisory forums. Section 50(1) of the Disaster Management Act stipulates that the MDMC's should report back to their councils through mayoral committees on an annual basis. Institutional support should be established at local government level for consultation between internal and external parties on issues relating to disaster risk management within the municipality. Section 51(1) of the Disaster Management Act (57 of 2002) indicates that there is no statutory requirement for local municipalities to establish the Municipal Disaster Risk Management Advisory Forum. However, district municipalities also form part of the local government sphere and are legally obligated (see s 7(2) (d–f), s 42(1–3), s 44(1) (b), s 44(3) (a–b), and s 47(2) of the Act) to manage disaster risk management competencies, and have a responsibility to establish district disaster management advisory forums. To be consistent with national and provincial approaches, local governments should also develop a disaster risk management framework for their area of jurisdiction.

Section 42 of the Disaster Management Act (57 of 2002) indicates that in order to ensure an integrated and uniform approach towards disaster risk management, each metropolitan and district municipality should establish and implement a Municipal Disaster Risk Management Framework, which is consistent with the provincial and National Disaster Risk Management Framework, in its area of jurisdiction. A Municipal Disaster Risk Management Framework is a document that steers disaster risk management activities at the local level. Furthermore, it provides operational guidelines to statutory functionaries on the implementation of operations in the district as well as at the local municipality, all the municipal departments operating in its area, the private sector, and non-governmental organisations taking part in disaster risk management (Van Niekerk, 2005). The formulation of a Municipal Disaster Risk Management Framework, in the case of MLM, will guide the development and implementation of disaster risk reduction strategies. In other words, the Municipal Disaster Risk Management Framework can be used as a guide to establish disaster risk management structures and strategies to effectively

mitigate the risks caused by sinkholes. In order to ensure cross-departmental consultation on disaster risk management strategies at local level, the Municipal Interdepartmental Disaster Risk Management Committee should be established.

The Municipal Interdepartmental Disaster Risk Management Committee (MIDRMC) is a platform where various municipal departments can consult each other and integrate their disaster risk management activities. It is responsible for ensuring that prevention and mitigation strategies are developed and implemented to ensure effective response to any potential calamitous event (Van der Waldt *et al.*, 2007:246; Munzelele, 2011). However, if the municipality decides not to establish such a committee, there should be an alternative structure in place to ensure that consultation takes place between government departments as well as allow the community to partake in disaster risk management activities. Once institutional arrangements have been established, then disaster risk assessments can be conducted. This is a crucial process because the effectiveness of a disaster risk management programme is determined by the quality of the disaster risk assessment outcomes.

3.3.2. KPA 2: Disaster Risk Assessment

Disaster risk assessment refers to systematic procedures that determine the nature and extent of hazard as well as societal vulnerability by analysing hazards and evaluating the conditions of vulnerability that can adversely affect people, property, livelihood and the environment (Basher, 2006: 2168; Perez-Lugo; 2001; Poolman, 2011: 12; Forbes-Biggs, 2011: 13). Therefore, the first step in reducing disaster risk is to identify the hazard and understand its nature, causes, severity, as well as the kind of damage it can do (Carreno *et al.*, 2007; Perez-Lugo; 2001; Forbes-Biggs, 2011:11). The objective of KPA 2 is to address the need for conducting disaster risk assessment. In support, sections 20, 33 and 47 of the Disaster Management Act further stipulate the importance of conducting disaster risk assessments in order to guide disaster risk reduction activities at national, provincial and municipal level.

There are various methods of conducting disaster risk assessment. The choice of method is determined by the nature of risk, the characteristics of the community at

risk, and the infrastructure that is likely to be affected (South Africa, 2003). However, the general disaster risk assessment process involves the following stages:

- Stage 1: Identifying the specific disaster risk to be assessed;
- Stage 2: Analysing the disaster risk concerned;
- Stage 3: Evaluating the disaster risk to be assessed in relation to other risks in order to set priorities; and
- Stage 4: Inform the on-going disaster risk assessment and planning processes. This stage involves monitoring disaster risks to ensure the effectiveness of risk reduction activities, and updating disaster risk assessment information, as well as distribute this information to all role-players (South Africa, 2003: 28).

Risk assessment requires a continuous monitoring of hazardous events, particularly those that are dynamic in nature (Basher, 2006: 2168; Perez-Lugo; 2001; Poolman, 2011: 12; Forbes-Biggs, 2011: 13). The assessment of risk will assist in supporting regular review and re-assessment of hazards, exposures and vulnerability as well as improving the understanding of evolving risk landscapes and risk knowledge as a result of new data. In order to reduce the impacts of disasters, people should be well-informed about the nature of hazards and measures that can be adopted to minimise their vulnerability.

A comprehensive risk assessment is the one that considers different types of calamitous events and their underlying drivers as well as recognising the importance of indigenous knowledge (Basher, 2006: 2168; Perez-Lugo, 2001; Carreno *et al.*, 2007). Indigenous knowledge is a crucial part of any risk assessment process because communities are knowledgeable on the types of disasters that occur in their environment and, in some cases, are even able to anticipate them (Basher, 2006: 2168; Perez-Lugo, 2001; Carreno *et al.*, 2007; Poolman, 2011: 13). Furthermore, active involvement of at-risk communities in the processes of disaster risk assessment will increase the likelihood of communities taking ownership of risk reduction initiatives (Basher, 2006; Carreno *et al.*, 2007; Perez-Lugo, 2001). This can be achieved by making use of instruments like the Vulnerability and Capacity Assessment model (VCA). This model follows a participatory and investigative approach which assesses the risk that individuals face in their communities, the

vulnerability that might emanate from such risks, and the capacity available to cope with hazards (Basher, 2006; Perez-Lugo, 2001). In other words, this model seeks to obtain the data necessary to assist people in preparing for hazards, and to prevent them from becoming disasters, or to mitigate the impact of disasters.

In this light, the NDMF (2005: 18) indicates that in order to strategically respond to the changing nature of disasters, all state departments must develop a monitoring system that is relevant to their functional responsibilities. These systems play a critical role in monitoring the effectiveness of disaster risk reduction activities and provide up-to-date data that can be used to continually update existing disaster risk assessments. The risk monitoring system consists of the following:

- Hazard tracking: system that monitors the physical activities that can cause a calamitous event. They provide seasonal and early warning information on approaching adverse weather conditions.
- Vulnerability and capacity monitoring system: Tracks the ability of areas, communities and critical services to withstand the external threat.
- Disaster event tracking: system that monitors the changing pattern of disaster risk. It monitors the increasing or decreasing frequencies of unclassified disaster incidents (South Africa, 2005: 35)

In the case of this study, conducting continuous disaster risk assessment in the MLM is essential because the nature of risk caused by sinkholes will be assessed as well as the vulnerability of communities and infrastructure. The Information gathered from disaster risk assessment can be used to develop strategies that would reduce the risk caused by sinkholes. For instance, awareness campaigns can be developed from the assessment results to inform the community about factors that exacerbate the formation of sinkholes and measures that should be undertaken to reduce the risks.

3.3.3 KPA 3: Disaster Risk Reduction

This KPA ensures that the development and implementation of disaster risk management plans and risk reduction programmes are executed in accordance with

the approved disaster risk management framework. Sections 25, 32 and 52 of the Disaster Management Act specifies the legal requirements for the preparation of disaster management frameworks and plans by national, provincial and local spheres of government. It emphasises the importance of planning and integrating disaster risk reduction principles and mitigation measures into future programmes and initiatives. Therefore, all the government spheres and other role-players involved in disaster management are required to develop and implement disaster risk management plans. The NDMF indicates that, in the development of disaster risk management plans, the Disaster Management Act (see s 25(1–2), s 38(1–2), and s 53(1–3)) takes into account the following issues:

- The unevenness in disaster risk management planning capacity and experience across the district municipalities; and
- National and provincial organs of the state engaging in disaster risk management for the first time should undertake a comprehensive consultation process before developing disaster risk management plans (South Africa, 2003: 41).

To address these issues, the NDMF provides for a phased approach to disaster risk management planning and implementation. Accordingly, planning can be used to design and implement activities that aim to reduce the risk because the impact of hazards can be increased by unplanned or inadequate human activities such as development in hazard-prone areas as well as inadequate safety measures (Sutanta *et al.* 2006: 245; Sakai, 1999). On this note, the NDMF outlines the following three levels of disaster risk management plans:

- Level 1 disaster risk management plan: It focuses on establishing institutional arrangements for disaster risk management, developing contingency plans to respond to the threats identified during risk assessment, identifying governmental and other role-players, and developing the capacity to generate a level-2 disaster risk management plan. This is only applicable to national, provincial or municipal entities that have never developed a disaster risk management plan;
- Level 2 disaster risk management plan: It is applicable to either provincial or municipal entities that have already developed institutional arrangements and are

working towards building the necessary capacity to execute disaster risk management activities. It entails the establishment of comprehensive disaster risk assessments, establishing formal consultative mechanisms for the development of disaster risk management projects, and introducing supportive information management and emergency communication systems.

- Level 3 disaster risk management: it is applicable to the provincial and municipal entity that has developed both the institutional arrangements for disaster risk management and necessary supportive capabilities. It must clearly outline the institutional arrangements for coordinating and aligning the plan with other government initiatives and involved role-players. Furthermore, it must reveal the evidence of informed disaster risk reduction and a continuous disaster risk monitoring system in order to reduce the vulnerability of communities and infrastructure from natural and developmental hazards.

Disaster risk management planning should be informed by disaster risk assessment results in order to set the priorities for dealing with a wide range of disaster risks (South Africa, 2003). In this regard, priorities must be set for identifying disaster risks. Therefore, disaster risk management priorities should be arranged to mitigate the impacts of the following disaster risks:

- Wide-area events (such as severe droughts, extreme weather, floods etc.) that are likely to affect more than one province or more than one district municipality;
- Recurrent events (such as informal settlements fires, communicable diseases that affect people and livestock) that occurs in most provinces and requires the national interventions or that occurs in district municipalities and requires the provincial interventions;
- Rare high-magnitude disasters risk (such as nuclear accidents, earthquakes, severe oil spills) with a potential for severe loss and which requires a certain level of special support that might not be available within the province;
- Disaster risks (unplanned cross-border movements or events that requires humanitarian assistance) that affect neighbouring countries and have an impact on South Africa, or that affect the province and have an impact on the neighbouring province (South Africa, 2003).

As indicated earlier, the effectiveness of risk reduction strategies is heavily influenced by disaster risk assessment. This implies that for the MLM to develop an effective sinkhole risk reduction strategy, a comprehensive sinkhole risk assessment process should be undertaken. The outcomes of a sinkhole risk assessment will guide the development and implementation of structural and non-structural strategies. For instance, residential areas will have to be planned with consideration of the structural measures (storm water drainage) to reduce the probability of sinkhole formation. While, the non-structural measures could involve raising awareness in the community about the risk factors that contribute to the formation of sinkholes.

3.3.4 KPA 4: Response and recovery

No matter how well a country or community plans to prevent disasters, there will always be a chance that a disaster will take place (Tierney *et al.*, 2001; Christoplos, 2001; Joyce, 2011; Chagutah, 2009). This implies that not all natural hazards can be prevented from occurring, but their impact can be reduced by developing and implementing an integrated policy that focuses on effective response to disasters and post-disaster recovery and rehabilitation. In this light, the objective of this KPA is to develop and implement an effective and appropriate disaster response and recovery approaches in a uniform manner. It also seeks to reduce the possible impact of hazards with regard to personal injury, loss of life, damage to infrastructure, property, as well as the environment. Furthermore, it also involves the implementation of rehabilitation and reconstruction strategies after the occurrence of a disaster.

According to Ngcamu (2011: 35) disaster response refers to all the actions that are taken by institutions and communities in the face of disasters, along with the implementation of a disaster preparedness plan and procedures. In this light, the fundamental aim of preparedness planning is to strengthen the capacity to respond to different hazardous situations that might affect a community by implementing a set of preparedness measures. Preparedness measures include early warning systems, on-going risk and vulnerability assessment, capacity building, the creation and maintenance of stand-by capacities as well as reserving necessary resources

(UN/ISDR, 2006:15; UN/ISDR, 2008: 20; Tierney *et al.*, 2001; Christoplos, 2001; Joyce, 2011; Chagutah, 2009). Building preparedness capacity requires an assessment of the systems in place and available resources. Capacity assessments can reveal hidden assets and available resources that can be built upon to strengthen preparedness and lead to a more predictable and efficient response and recovery process (Allen, 2006; Kadzatsa, 2011; Tierney *et al.*, 2001). Capacity building activities should include measures to analyse responses to previous disasters and to incorporate lessons learnt into future capacity-building strategies.

In light of the above, the NDMF stipulates that, the responsibility for co-ordinating the response to a specific disaster should be allocated to a state department which holds expertise in that particular type of a disaster, and other stakeholders will provide support (South Africa, 2002: 59). For instance, in the case of floods, the Department of Water Affairs and Forestry will assume the primary responsibility. Furthermore, in terms of integrated reconstruction and rehabilitation, the state organ tasked with the primary responsibility must establish a project team that is mandated to assist disaster victims in recovering from the impact and also to restore the affected infrastructure (South Africa, 2002). During the reconstruction process, the team must incorporate appropriate mitigation measures to reduce the impact of future disasters and report its progress to the NDMC. It is essential to indicate that during a disaster or when a disaster threatens to occur, the MDMC (Municipal Disaster Management Centre) has the responsibility to guide and support the relevant stakeholders in the case of metropolitan municipalities and local municipalities within a district. Furthermore, it should also utilise the municipal infrastructure and other resources available to support the local disaster risk reduction initiatives (South Africa, 2002: 14). In the case of MLM, KPA 4 implies that preparedness measures such as training should be provided for both the community members (to enlighten them about the signs of sinkhole formation and encourage them to report the signs as soon possible) and officials (so they can conduct assessments and rehabilitate the sinkhole) to reduce the risk of injury, loss of life, or damage to infrastructure. The subsequent section will discuss the second enabler as it corresponds with the HFA's priorities for action.

3.3.6 Enabler 2: Education, Training, Public Awareness and Research

According to Patel and Izadkhah (2008) the crux of developing a disaster resilient society is heavily influenced by the success of disaster reduction education. Formal and informal education can be used to distribute information and increase understanding about disaster risks, teach preparedness, as well as demonstrate possible ways to react during disasters (UNESCO, 2005; Burby *et al.*, 2007: 256; Clerveaux & Spence, 2009: 209). In this light, section 15 and 20 (2) of the Disaster Management Act encourages a culture of risk avoidance, promotion of education and training, as well as research into all aspects of disaster risk management. To achieve this, this enabler promotes a culture of risk avoidance by capacitating the role-players through integrated education, training, and public awareness programmes. It addresses the requirements for the development and implementation of national education, training and research, as well as integrated public awareness – including the use of media and the inclusion of disaster risk management in the school curricula.

Building a disaster-resilient community through formal education entails, amongst others, the incorporation of disaster reduction curricula or lessons in schools and post-school institutions because it is believed that children and young people are more receptive to new information and they can also act as a channel for transferring knowledge to their families (Burby *et al.*, 2007: 256; Clerveaux & Spence, 2009: 209). The NDMF reiterates this by stipulating that disaster education must be integrated into primary and secondary school curricula and schools should be regarded as focal points for raising awareness about disaster risk reduction. Government officials should also receive extensive training on disaster risk reduction and other relevant fields such as development planning, hazard identification and assessment, and participatory rural appraisal (Mercer *et al.*, 2009; Rambau *et al.* 2012). Furthermore, informal training that focuses on disaster risk awareness, disaster risk reduction, and preparedness should also be presented to community members. Informal training (transmitting information outside the standard of a school setting) can be used to broaden the knowledge of people who are already familiar with various risk reduction skills that they acquired over a period of time through experience as well as community practices (Mercer *et al.*, 2009; Rambau *et al.* 2012;

UNESCO, 2005; Pearce, 2002; Izadkhan & Hosseini, 2005; Clerveaux & Spence, 2009: 221). In other words, training (formal and informal) can be used as platform for raising awareness about hazards, vulnerabilities, risks, and how to reduce disaster impacts from vulnerable communities and decision makers. It is essential to disseminate information on hazards and vulnerability in a manner that the targeted group will understand and, if possible, it should be accompanied by practical actions that can be undertaken to reduce the risk as well as the expected benefits of such actions (Chagutah, 2009: 116; Poolman, 2011:12). The NDMF indicates that the Disaster Management Act calls for continuous research to be conducted in all aspects of disaster risk management (Mercer *et al.*, 2009; Rambau *et al.* 2012).

The NDMC is responsible for developing a disaster risk reduction research programme which is linked to the municipal IDP process in order to effectively guide disaster risk management planning and implementation. The NDMC must develop the following processes in order to develop a focused research agenda:

- Consultation between disaster risk scientists and disaster risk reduction professionals in order to identify priorities for collaborative research and development as well as ways to implement such initiatives;
- Auditing of the existing research initiatives and programmes in order to identify those that contribute to the understanding of disaster risk management processes and provide insight into effective disaster risk reduction strategies;
- Consultation with national and international agencies that support research for promoting disaster resilience and co-ordinate funding support for disaster risk management research.
- Developing an integrated disaster risk reduction research programme as well as the mechanisms to publicise the research results (Mercer *et al.*, 2009; Rambau *et al.* 2012).

For the MLM, enabler 2 implies that formal and informal education can be used as a platform to raise awareness about the risk of sinkholes as well as share information regarding measures that can be implemented to reduce the risk. It can be argued that the incorporation of sinkhole risk reduction in MLM schools can contribute towards building a resilient community to sinkholes because it is believed that

children and young people are more receptive to new information and they can also act as a good channel for transferring knowledge to their families (Burby *et al.*, 2007: 256; Clerveaux & Spence, 2009: 209). The above section discussed South African Disaster Management legislation and related structures in detail. It also indicated how structures are formed and how they function in national, provincial and local government.

Henceforth, the following section will provide a discussion regarding the mining and the environmental management legislation that focus on regulating mining operations that might have adverse impact on the environment (dewatering dolomitic aquifers and compromise ground stability which may result in the development of sinkholes).

3.4 Mining and Environmental Management Legislation

The extraction and processing of mineral resources is widely considered as one of the most environmentally and socially disruptive business activity (Jenkins & Yakovleva, 2006: 272). This is reflected in the context of the study area. For instance, the occurrence of sinkholes in the MLM as a result of dewatering dolomitic aquifers (which compromised the ground stability) by mines caused the following catastrophic events:

- Sinking of the West Driefontein crushing plant as well as the business sector of the Carletonville Township (known as Khutsong) into sinkholes;
- The death of a family of five at Blyvooruitzicht due to a sinkhole;
- Drying up of boreholes used for farming activities;
- Cracking walls of local houses; and
- Deterioration of water and sanitation infrastructure (Winde & Stoch, 2010; Van Eeden *et al.*, 2003; Van Eeden, 2006; Ngcobo, 2006; Swart *et al.*, 2003).

Section 24 of the South African Constitution (1996) stipulates that:

> Everyone has the right to an environment that is not harmful to their health or wellbeing; and to have the environment that is protected for the benefit of present and future generations, through reasonable legislative and other measures that prevent pollution and environmental degradation; promote conservation; and secure ecologically sustainable development and use of natural resources while promoting justifiable economic and social development.

In this regard, several pieces of legislation (see table 3.2) were compiled to protect various aspects of the environment. Examples of these are the National Water Act (36 of 1998), National Environmental Management Act (107 of 1998), Mineral and Petroleum Resources Development Act (28 of 2002), Biodiversity Act (10 of 2004), Waste Act (59 of 2008), as well as the Environmental Realisation Act (51 of 1997). However, for the purpose of this study the focus will be limited to the National Environmental Management Act as well as the Mineral and Petroleum Development Act because they focus on regulating mining operations that might adversely affect the environment. In the case of the MLM it can be argued that the dewatering of the dolomitic aquifers contravenes Section 24 of the Constitution because it compromises the ground stability which then leads to the formation of sinkholes (which means a harmful environment for the MLM residents).

3.4.1 National Environmental Management Act

In order to comply with Section 24 of the Constitution, Section 2 of the National Environmental Management Act (107 of 1998) (NEMA) prescribes the environmental management principles that guide the administration and execution of the environmental requirements for current and future mining operations. In this regard, Section 2 (4) of the NEMA outlines the following principles for environment-related operations:

- Pollution and environmental degradation should be avoided or, in cases where they cannot be avoided, they should be minimised and remedied;

- The development, use and exploitation of renewable resources and the ecosystem should not exceed the level beyond which their integrity is jeopardised;
- The negative impacts on the environment and on people's rights should be anticipated and prevented; if they cannot be altogether prevented they should be minimised and remedied;
- The cost of remedying pollution, environmental degradation or minimising further environmental damage should be paid by those responsible for harming the environment.

The environmental management principles, if properly implemented, will ensure that mining organisations (in the MLM) do not focus on maximum production only (by dewatering dolomitic compartments for the sake of mining operations), but consider the risks caused by the dewatering process (compromising the ground stability) which could pose a threat to residents and infrastructure. The environmental management principles compel the mining organisations to anticipate the risks that may arise as result of their operations. Furthermore, the principles indicate that the cost of rehabilitating the environment should be paid by those responsible for harming it. It can be argued that, since the dewatering of dolomitic aquifers by mines contribute to the formation of sinkholes (as a result of compromised ground stability), the mining organisations should contribute to the process of reducing the risks associated with the formation of sinkholes in the area. For instance, by allocating a budget that can be used for awareness campaigns and the rehabilitation of sinkholes.

Furthermore, Section 10 of the NEMA requires each department (at national level) involved in the protection of the environment, to prepare an environmental management plan as well as the environmental implementation plan (South Africa, 1998). Both the environmental management plan and environmental implementation plan can be used to:

- co-ordinate environmental policies, plans, programmes and decisions of the various national, provincial and local departments – entrusted with powers and duties aimed at the achievement, promotion, and protection of a

sustainable environment – in order to avoid duplication and promote consistence across all the spheres;

- implement the principles of co-operative government as outlined in Chapter 3 of the Constitution;
- enforce protection of the environment across the country as a whole;
- regulate unnecessary actions by provinces in respect of the environment that are prejudicial to the economic or health interests of other provinces or the country as a whole; and
- enable the Minister to monitor the promotion and protection of a sustainable environment (South Africa, 1998).

In order to comply with the environmental management plan and environmental implementation plan, every sphere of government must exercise all its functions to protect the environment in accordance with the environmental implementation plan or the submitted environmental management plan. Provinces must also ensure that the relevant provincial environmental implementation plan is compiled by each municipality within their area of jurisdiction and that municipalities adhere to the relevant environmental implementation and management plans, as well as the principles of developing policies and programmes (South Africa, 1998).

In the case of the MLM, the development and implementation of sinkhole risk reduction strategies must take into cognisance the environmental plan and environmental implementation plan in order to achieve consistence with the provincial and national spheres of government. It is essential to indicate that the legislation does not provide a clear guideline regarding the relationship between environmental management and disaster management. It can be argued that when the NEMA was approved in 1998, while the NDMA was still in its conceptual phase (the Inter-Ministerial Committee for Disaster Management was only established in 1997 to develop disaster management legislation). The following section will highlight the aspects of the Mineral and Petroleum Resource Development Act which

regulate mining operations to comply with the environmental management requirements.

3.4.2 Mineral and Petroleum Resources Development Act

Section 37 of the Mineral and Petroleum Resources Development Act (MPDRA) reiterates that the principles of environmental management outlined in Section 2 of the NEMA should be applied to all current and future mining operations. In addition, Section 38 indicates that the holder of the mining right or mining permit should investigate, assess and communicate the impact of the mining operations on the environment, as well as the socio-economic conditions of any person who might be affected by such mining operations. The right / permit holder will be held responsible for any mining-related damage to the environment inside or outside the boundaries of the area to which such right relates. Consequently, it can be argued that, in order to comply with Section 38 of the MPRDA, the mining organisations in the MLM should be held accountable for the occurrence of sinkholes in the area due to the dewatering of dolomitic aquifers.

As in Section 10 of the NEMA, Section 39 of the MPDRA requires the mining permit holders to develop an environmental management plan which establishes the baseline information regarding the affected environment, and describe the manner in which the operation which causes the environmental degradation will be modified or controlled. In the case of the MLM, sinkholes should be included as part of other environmental damages as result of mining operations and mining organisations should describe the remedial measures for sinkholes as part of the environmental management plan.

3.5 Conclusion

In conclusion, this chapter discussed the South African disaster management law that guides the implementation of disaster risk management activities as well as the mining and environmental management legislation. It specifically highlighted the fact that South Africa did not have a comprehensive approach to deal with disasters

before 1994 and the focus was primarily on response and recovery. In response to the request made by the United Nations to reduce the impacts of natural hazards, South Africa (as a member state) dedicated itself to develop an approach that was in line with the international practices of managing disasters. As a result, the government established an Inter-Ministerial Committee in 1997 which was responsible for developing disaster management legislation for South Africa. In the beginning of 2000, the South African Disaster Management Bill was availed for public discussion and on January 2003, the new Disaster Management Act 57 of 2002 was promulgated.

Apart from the Disaster Management Act, South Africa also has a National Disaster Management Framework (NDMF) which steers the development and implementation of disaster management approaches. The National Disaster Management Framework (NDMF) is divided into four Key Performance Areas (KPAs) – which are guided by the objectives set out in the Disaster Management Act – and three enablers, which have to be present for the successful implementation of the KPAs. The first KPA oversees the existence of an integrated institutional capacity for disaster risk management in all government spheres (national, provincial and local). The second KPA deals with issues relating to conducting disaster risk assessment in order to steer risk reduction initiatives, while the third KPA deals with issues relating to disaster risk management planning in order to reduce disaster risks. The last KPA deals with issues relating to effective response and recovery from the impacts of disasters. The second enabler focuses on promoting a culture of risk avoidance by capacitating the role-players through integrated education, training and public awareness programmes. It addresses the requirements for the development and implementation of national education, training and research as well as integrated public awareness including the use of media and the inclusion of disaster risk management in the school curricula.

In terms of regulating the adverse impacts of mining operations on the environment, Section 2 of the NEMA stipulates that any disturbance of ecosystems, pollution, and environmental degradation should be avoided or, in cases where they cannot be avoided, they should be minimised and remedied. The use and exploitation of non-renewable natural resources should be performed in a responsible and equitable

manner, taking into account the consequences of the resource depletion. The use and exploitation of renewable resources and the ecosystem should not exceed the level beyond which their integrity is jeopardised. The negative impacts on the environment and on people's environmental rights should be anticipated and prevented; if they cannot be altogether prevented they should be minimised and remedied. Finally, the cost of remedying environmental damage should be paid by those responsible for harming the environment.

Chapter 4

Research Methodology

4.1 Introduction

The previous chapter presented the legislative framework guiding the implementation of disaster management as well as environmental management legislation in South African. This chapter will present in-depth discussion of various aspects of the research methodology as they were applied in the process of collecting data to answer the research questions. The discussion in this chapter focuses, specifically, on an explanation of the research design and motivation for the use of qualitative research design. Thereafter, a detailed discussion of the data-collection methods is provided. In this study, data was collected by means of unstructured, semi-structured, as well as focus group interviews. And the Hyogo Framework for Action was used as an analysis tool. Issues relating to the validity and reliability of the study are also outlined. Finally, the chapter will be concluded by describing the ethical considerations that influenced the study.

4.2 Research design

Research design can be described as a blueprint for conducting a study in such a way that maximum control is gained over the factors that could interfere with the validity of the research results (Bell, 2005:159, Creswell, 2003, Berg, 2006, Greener, 2011 and Guthrie, 2010). The research design can be regarded as the researcher's general plan for obtaining answers to the research questions that guide the study. Designing a study enables the researcher to plan and conduct the study in a way that will obtain the envisaged results, and therefore increase the chances of obtaining information that could be associated with the real situation (Bell, 2005:159, Creswell, 2003, Berg, 2006, Greener, 2011 and Guthrie, 2010). This study utilised the qualitative research design to gather information about the factors that contribute to the formation of sinkholes; how sinkholes affect the economic developmentof the MLM; and if strategies were implemented to mitigate the formation and impacts of sinkholes.

4.2.1 Qualitative research design

Qualitative research is a process of studying a phenomenon in its full complexity, portraying its multi-faceted forms, and trying to simplify what was studied or observed (Leedy & Ormrod, 2001; Struwig and Stread, 2007). It recognises that research takes place within a specific context and individuals are influenced by the environment they live in. Thus, the opinion of participants should not be seen in isolation but as influenced by their environment (Blaikie, 2000: 233; Struwig and Stread, 2007: 71).

Qualitative data consist of open-ended information that the researcher gathers through different types of interviews with participants. Generally, questions are open-ended in nature to keep conversation going in order to obtain more detailed information (Pope & Mays, 2006). Specifically, open-ended questions create a platform to gain more insight into a person's feelings and perspectives (Pope & Mays, 2006). Qualitative information can also be collected by observing participants or the site of research, gathering documents from private (diaries) or public sources (such minutes of meetings) or collecting audio-visual materials (video recordings) (Pope & Mays, 2006). Qualitative data (words, photos, text) is analysed by aggregating the words or images into categories of information and present the diversity of ideas gathered during the collection of data (Creswell, 2006: 6).

Qualitative research methodology has, amongst others, the following characteristics:

- It is able to provide a description of people's personal experiences regarding a phenomenon;
- It is able to describe complex phenomena;
- It describes the phenomena as they are situated and embedded in local context; and
- It is able to determine the cause of a social problem (Leedy & Ormrod, 2001; Struwig and Stread, 2007).

In this light, a qualitative approach was selected for the study because it would enable the researcher, through the use of structured, unstructured, and focus group interviews, to gather:

- The views of MLM's community members regarding the formation and impact of sinkholes;
- Information regarding the existence of mitigation and response strategies for the formation of sinkholes; and
- Information about the management of water and sanitation facilities and how they were monitored in order to avoid leakages.

The following section will provide a comprehensive discussion regarding the data collection tools utilised for the study.

4.3 Data collection tools

A qualitative research design provides the researcher with a variety of tools that can be utilised to achieve the research goal. In the case of this study, unstructured, semi-structured as well as focus group interviews were selected as data collection tools. These tools are comprehensively discussed in the section to follow, starting with a brief description of the literature review, and then followed by the introduction of each research tool.

4.3.1 Literature review

In order to gain an understanding of the factors that contribute to the formation of sinkholes in a dolomitic area such as MLM, an extensive literature review was conducted. Literature review is a process of reading, analysing and summarising the scholarly work on a particular topic (Hofstee, 2006; Greener, 2011; Berg, 2006). Amongst others, the purpose of literature review is to show:

- That the researcher is aware of what is going on in practice;
- How the current research fits into the research that has already been conducted;
- How the researcher's work will lead to new knowledge; and

- That there is a theoretical basis for the research to be conducted (Hofstee, 2006: 91; Creswell, 2003, Berg, 2006, Greener, 2011; Mouton, 1996).

For the purpose of this study, academic documents regarding the formation of sinkholes in dolomitic areas, such as MLM, and the associated impacts were perused. These documents were consulted to form a theoretical framework for this research.

4.3.2 Unstructured, semi-structured, and focus-group interviews as methods of data collection

The qualitative research design enables the researcher to utilise various types of interviews as data collection methods. Interviews can be conducted in such a way that interviewees feel as comfortable as if they were engaging in a normal conversation. It is essential to note that the researcher's role as the interviewer determines the quality of interview and both the interviewer and interviewee are involved in the process of answering the research questions (Rechards & Morse, 2007: 113; Greef, 2007:287; Flick; 2009). The interviewer should always be an active listener and has to be responsive and involved without interrupting the interviewees when responding (Rechards & Morse, 2007:113). This enables the researcher to steer the interview in such a way that the interviewee provides as much information as possible about the phenomenon under investigation. For this research, interviews were selected because they would enable the interviewees to provide comprehensive responses regarding the impact of sinkholes in MLM as well as the strategies implemented to mitigate the risks and to recover from the damage caused by sinkholes.

4.3.2.1 Unstructured interview

Unstructured interviews can be described as 'a conversation with purpose' and is said to 'formalise basic conversation' (DiCicco-Bloom & Crabtree, 2006; Greef, 2007: 292). This interview method allows the researcher to identify the key members (informants) who would be interviewed (DiCicco-Bloom & Crabtree, 2006; Greef, 2007: 292). Key members are selected on the basis of their roles in the community

(i.e. ward councillors and municipal officials) and also their knowledge with regard to the phenomenon under investigation (strategies implemented to manage as well as mitigate the impact of sinkholes) (DiCicco-Bloom & Crabtree, 2006: 315). Unstructured interviews enabled the researcher to gain in-depth information about the community's perspectives regarding the formation and impact of sinkholes on the economic development (DiCicco-Bloom & Crabtree, 2006; Greef, 2007: 292).

Two sessions of unstructured interviews were conducted. Firstly, with the senior official in disaster management department, to gain in-depth information on the mitigation and response strategies with regard to the formation of sinkholes. The senior disaster management official was purposefully selected as he is in a managerial position and is therefore responsible for the development and implementation of sinkhole risk reduction and response strategies. Unstructured interviews also enabled the researcher to gain an in-depth understanding of the strategies used to manage the formation of sinkholes, through the use of follow-up questions (DiCicco-Bloom & Crabtree, 2006; Greef, 2007: 292; Pope & May 2006).

Secondly, unstructured interviews were conducted with the ward councillors of areas affected by the formation of sinkholes in order to obtain the community's views regarding the impact of sinkholes on the economic developmentand what they thought should be done to solve the problem. Ward councillors were selected because they are community members who are elected by their communities to represent their concerns at the local authorities. They serve as a link between the community and local authorities. Ward councillors were selected as a group to be interviewed because they work with community members on daily basis, and would therefore be aware of interests as well as the grievances of the community. These unstructured interviews were supplemented by semi-structured interview.

4.3.2.2 Semi-structured interview

Semi-structured interviews combine two types of interview techniques, namely the unstructured interview and the structured interview (Struwig & Stead, 2001:98; Greener, 2011; Mouton, 1996). When conducting a semi-structured interview, open-ended questions have to be prepared and arranged in a logical order (Rechards & Morse, 2007:114; Pope & Mays, 2006). This interview method makes it possible to

arrange the topics according to their interconnectedness (Rechards & Morse, 2007:114; Greef, 2007:296, Greener, 2011; Mouton, 1996). Semi-structured interviews are flexible in the sense that they enable the researcher to gain essential information by allowing the interviewees to be more precise with details. This makes it ideal for studying an unfamiliar phenomenon such as water and sanitation facilities and their effect on dolomite (DiCicco-Bloom & Crabtree, 2006; Greef, 2007:293,296). It is also essential to note that even though the questions were prepared in advance, the interviewer allowed the conversation to flow as natural as possible, just like in unstructured interview, and asked questions in such a way that they encouraged in-depth and detailed answers (Greener, 2011; Mouton, 1996).

A semi-structured interview was conducted with the senior official from the MLM Water and Sanitation Department regarding the monitoring and maintenance of water and sanitation infrastructure. This official was purposefully selected because she is in a managerial position and is therefore responsible for prioritising the maintenance of water and sanitation facilities. Thus, she was able to provide information about the installation of water and sanitation system and how they were managed and monitored in order to avoid leakages. Information gathered from this interview was used to analyse the method of monitoring and maintaining water and sanitation infrastructure in order to reduce water seepage, which contributes to the formation of sinkholes.

4.3.2.3 Focus group interview

Focus group interviews can be defined as a tool used to collect research data from a group which deliberates on topics delineated by the researcher (Morgan, 1996; Langford & McDonough, 2003). It enables participants, ranging from a group of six to ten members, to discuss issues related to the research problem under the supervision of the researcher who steers the discussions (Morgan, 1996; Langford & McDonough, 2003; Boeije, 2010: 64; Tong *et al.*, 2007: 351).

Three sets of focus-group interviews were conducted with the community members who live in the areas that are affected by the formation of sinkholes, to acquire individual and shared views regarding the impact of sinkholes on the community as

well as their perceptions on possible measures to reduce the risk (Morgan, 1996; Langford & McDonough, 2003). After data collection process, the information was analysed by using the Hyogo Framework for action to assess whether the MLM is pro-actively managing and mitigating the impacts of sinkholes on its economic developmentas well as explore the strategies implemented to recover from those impacts.

4.4 Data analysis tool: Hyogo Framework for Action (HFA)

The HFA is a global guideline that emphasises the pro-active approach toward disasters (disaster risk reduction) rather than responding to the impacts caused by disasters**.** Disaster risk reduction is a framework which intends to systematically prevent and mitigate disaster risks with regard to loss in lives and socio-economic assets of communities and countries (UN/ISDR, 2005: 3, Olowu, 2010: 305; Walker,2005; HFA:2010; Bhat: 2007). Since the HFA prescribes that pro-active actions should be adopted in order to prevent or lessen disaster risks, it was selected because its priorities for action formed applicable categories of data analysis for this research. Its relevance stems from the fact that it seeks to investigate the factors that contribute to the formation of sinkholes in the MLM with the intention of developing a strategy to pro-actively prevent and lessen the impacts of sinkholes. The HFA is also useful because it takes into account the roles of different stakeholders in order to address the challenge. In this regard it made it possible to capture the community members' perspectives on formation and impact of sinkholes, as well as assisted in exploring the strategies implemented by MLM to prevent and lessen the risks caused by sinkholes.

The data collected was analysed by comparing the strategies implemented by the MLM (to manage sinkholes) with the HFA priorities for action, because it would reveal whether the process of reducing the risks associated with sinkholes was prioritised in the MLM and whether the risk reduction strategies were developed and implemented. It assisted in determining whether there were mechanisms in place to assess and monitor factors contributing to the formation of sinkholes as well as identify early warning signs. It also helped to assess whether innovation and education were used to create awareness with regard to the factors that contribute to

the formation of sinkholes. In addition, it was also utilised to explore the strategies employed by the MLM and community members to reduce the underlying sinkholes risk factors. Furthermore, it was used to determine how the MLM and the community prepared themselves to respond effectively towards the formation of sinkholes as well as recover from their associated impacts.

4.5 Measures to ensure reliability and validity of the study

According to Tashakkori (2009) validity and reliability are two aspects that should not be neglected or underestimated in research because failing to do so could lead to the results of the study being worthless and inaccurate. Validity can be defined as the extent to which an instrument measures and reflects the real meaning of the phenomenon under investigation (Ihantola & Kihn, 2011: 42; Golafshani, 2003: 599). Reliability refers to the consistency of a particular instrument: meaning if the instrument is applied repeatedly under the same conditions it should yield the same results (Ihantola & Kihn, 2011: 42; Golafshani, 2003: 599). The issues of validity as it pertains to the study will be discussed first, then, followed by reliability.

4.5.1 Validity of the study

This section will discuss issues of validity relating to the qualitative research design. In qualitative research, validity refers to the research being credible, trustworthy and defensible. In this regard, data triangulation was used to ensure the validity of the results. Data triangulation refers to the use of multiple data sources in a single study (Johnson, 1997:289; Guion *et al.* 2011; Creswell *et al.*, 2003; May, 2001; Teddlie & Tashakkori, 2009). Data triangulation entails the collection of data from different participants at different times with the purpose of increasing the validity of a study (Johnson, 1997:289; Yeasmin & Rahman, 2012). Therefore, to ensure the validity of this study, data was collected from the various participants such as senior disaster management official, senior official at the Water and Sanitation Department, ward councillors and community members at different times.

4.5.2 Reliability of the research study

Reliability is a concept that is applied in quantitative research to produce consistent results (Golafshani, 2003:601, Onwuegbuzie & Johnson, 2006; Guion *et al.*, 2002). However, producing consistent results in qualitative research often poses challenges because the variables are constantly changing (Golafshani, 2003: 60; Onwuegbuzie & Johnson, 2006; Guion *et al.*, 2002). To ensure the reliability of research results, a sample should consist of participants who best represent or have the knowledge of the research topic (Morse, 2002). Sampling adequacy ensures the effective saturation of quality data and also ensures that sufficient data is captured to account for all aspects of the phenomenon. For this study, the research sample consisted of participants (ward councillors and community members) who had first-hand experience of the effects of sinkholes on the socio-economic aspects of their communities (Morse *et al.*, 2002; May, 2001: 93; Teddlie & Tashakkori, 2009: 168). Senior officials from the MLM's Disaster Management and Water and Sanitation departments were reliable sources of information because they were directly involved in the planning and implementation of sinkhole risk reduction strategies. Ward councillors and community members, on the other hand, were also reliable sources of information regarding the impacts of sinkholes on the economic developmentof their communities.

In terms of confirming the reliability of consulted documents, instrument reliability and analyst reliability were applied. Instrument reliability is a process of comparing similar documents at various levels in time, while analyst reliability refers to the process of comparing several research results at a certain level (Mogalakwe, 2006; Morse, 2002; Golafshani, 2003: 601, Kirk & Miller, 1989; Huysamen, 1996). To adhere to these forms of reliability, documents with different publication dates were perused to track the occurrence, impacts as well as the factors that contributed to the formation of sinkholes at MLM. For instance, the majority of consulted documents constantly referred to the work of Butrick (1995, 1998, and 2011) as essential documents in order to understand the formation of sinkholes in areas underlain by dolomite.

4.6 Limitations of the study

The outcomes of the study cannot be generalised to all areas where sinkholes have occurred. This study focused only on the impacts of lowering water tables in dolomitic compartments, as well as excessive water seepage in dolomitic areas and how these factors contribute to the formation of sinkholes. Another aspect that further narrowed the study was to determine how sinkholes affected the economic developmentof MLM.

4.7 Ethical consideration of the study

Conducting social research is an ethical enterprise and research ethics provides researchers with a guidelines on how to conduct research in a scientific acceptable manner (Bless *et al.*, 2006:140; Struwig and Stead, 2001: 67; Wisker, 2001: 168; Neuman, 2006:129). The rationale behind the ethics of research is to prohibit researchers from engaging in scientific misconduct like distorting and inventing data, as well as plagiarising the work of others (Neuman, 2006: 129; Wisker, 2001: 168).

The researcher ensured that the research was ethically conducted at all times. Participants were requested to sign informed consent forms acknowledging their willingness to participate, before they were interviewed. Interviewees were also informed that their participation would be voluntary and that they would not be stopped from discontinuing their participation at any point during the interview. Each respondent was guaranteed absolute confidentiality. The research was also conducted in an environment that was safe and free from threats, where the interviewees felt comfortable.

4.8 Conclusion

In conclusion, the goal of this research is to determine the causes of sinkholes as well as their impacts on the economic developmentof the MLM with a view of developing a strategy to reduce the risks emanating from sinkholes. To achieve this objective, qualitative research design was utilised because it is able to describe the phenomena as they are situated in the local context, determine the cause of a social

problem, and it is also able to provide a description of people's personal experiences of the phenomenon (Creswell, 2006: 9).

Data was collected by means of unstructured, semi-structured and focus group interviews with the key informants. The semi-structured interviews enabled the interviewer to tick responses on a pre-prepared schedule, which allowed the interviewer to leave the interview with a set of responses that were easily recorded, summarised and analysed. Unstructured interviews were utilised to enable the researcher to gain an in-depth understanding of the problem being investigated (Guthrie, 2010:119). Focus group interviews were conducted to acquire individual and shared views regarding the impacts of sinkholes on the community as well as their perceptions on possible measures to reduce the risk (Morgan, 1996; Langford & McDonough, 2003).

The collected data was analysed by comparing the strategies implemented by the MLM to manage sinkholes with the HFA priorities for action, because it would reveal whether sinkhole risk reduction was prioritised by the MLM and whether risk reduction strategies were developed and implemented. It also assisted in determining whether there were mechanisms in place to assess and monitor aspects contributing to the formation of sinkholes as well as to identify early warning signs. In addition, it helped to assess whether innovation and education were utilised to create awareness of the factors that contribute to the formation of sinkholes. Strategies employed by the MLM to reduce the risk factors associated with sinkholes were also explored. Finally, using the HFA as an analytical framework helped to determine how the MLM and the community prepared themselves to respond effectively towards the formation of sinkholes as well as recovering from the associated impacts.

The triangulation of data helped to ensure the validity of the study. Data was collected from a variety of participants at different times. Furthermore, Instrument reliability and analyst reliability were also applied to ensure the reliability of the consulted documents. To adhere to these forms of reliability, documents with different publication dates were perused to track the occurrence, impacts, as well as the factors that contribute to the formation of sinkholes in MLM. Most of the

documents consulted repeatedly referred to the work of Butrick (1995, 1998, and 2011) as essential to understand the formation of sinkholes in areas underlain by dolomite.

Furthermore, the research process remained ethical at all times and participants were requested to sign inform consent forms before being interviewed. Interviewees were also informed that their participation was voluntary and that they were free to discontinue their involvement at any point during the interview. The next chapter will present the findings of the research and utilise the HFA as an analysis tool.

Chapter 5

Empirical findings and analysis

5.1 Introduction

The objective of this study was to investigate the causes of sinkholes and effects thereof at the Merafong Local Municipality's communities. A qualitative research design was used as a means to carry out the research. Qualitative research allowed the researcher to utilize the research instrument in the form of interviews, which allowed the participants to comprehensively describe the phenomena under investigation. This chapter will present the empirical findings and making use of the HFA's priorities for action as an analysis tool. The following section will outline the context of the study.

5.2 Research Context

The MLM is an area located in the West Rand District Municipality (WRDM). This district is known to be underlain by dolomite (Swart *et al.*, 2003; Kirsten *et al.*, 2006). Dolomite is a soluble carbonated bedrock (Swart *et al.*, 2003; Kirsten *et al.*, 2006; Zhou, 1997:50). The constant exposure of dolomite to rainwater as well as human-related activities (such as ground water extraction, leakage from water pipes and sewerage systems) dissolve the rock over time as these substances penetrate through rock joints to form openings beneath the surface which may result in sinkholes (Swart *et al.*, 2003; Kirsten *et al.*, 2006; Zhou, 1997:50; Van Eeden *et al.*, 2007). Sinkholes are either caused by the hollowing out or formation of void below the earth's surface as a result of normal geological processes, or they may have anthropogenic causes. Furthermore, anthropogenic causes such as the construction of roads, township development and associated services, groundwater extraction and groundwater recharging may also give rise to the formation of sinkholes (Haarhof, 2011; Buttrick & Van Schalkwyk, 1998; Ngcobo, 2006; Watermeyer *et al.*, 2001; Watermeyer *et al.*, 2002; Swart *et al.*, 2003; Gutierrez, 2006; Buttrick *et al.*, 2011).

In order to gain an understanding of the factors that contribute to the formation of sinkholes in MLM, it was necessary to include the following groups:

- Ward councillors (in affected wards): ward councillors work with community members on a daily basis, and are therefore likely to be aware of the interests and concerns of the community.
- Community members (who live in areas that are affected by sinkholes): In order to gain individual as well as shared experiences and perceptions regarding the impacts of sinkholes and possible measures to mitigate the risk.
- A senior official at MLM's Water and Sanitation Department (for the monitoring and maintenance of water and sanitation infrastructure) and;
- A senior disaster management official designated by the WRDM to implement disaster risk management services in MLM (to gain information on the mitigation as well as response strategies for sinkhole formation).

The following section will briefly discuss the research participants.

5.3 Research participants

A total of 4 groups participated in the interviews: these were the ward councillors, a senior official at the MLM's Water and Sanitation Department, a senior Disaster Management official responsible for the implementation of disaster risk management activities in MLM (from the district level), and community members (focus groups). The ward councillors represented all six wards affected by the occurrence of sinkholes in MLM. The MLM's Department of Water and Sanitation was selected because excessive water seepage due to leaking water or sewage pipes could lead to the formation of sinkholes, and the official's inputs on water and sanitation infrastructure maintenance was required. The WRDM renders disaster management services to all the municipalities in its area of jurisdiction, including MLM. The senior official from the WRDM Disaster Management Department was selected to provide in-depth information regarding the development and implementation of sinkhole risk reduction and response strategies. Finally, the focus groups were conducted to acquire individual and shared views regarding the impacts of sinkholes on the

community as well as their perceptions on measure to reduce the risk. All the interviews were conducted in person to enhance the response rate. The selected participants formed a 100% sample, as they represented individuals who are affected as well as directly responsible for managing the risk associated with dolomite.

5.4 Data analysis

According to De Vos *et al.* (2005) and Mouton (2001), data analysis is a process of reducing the large quantity of the collected data in order to make sense out of it. In this regards, data was reduced by summarising the "raw" interview transcripts and categorise the information into themes relating to the HFA's priorities for action. The following section will present the empirical findings of the interviews conducted in MLM.

5.5 Findings

The interviews were conducted with six ward councillors and a senior official at the Water and Sanitation Department as well as a senior Disaster Management official at the West Rand District Municipality responsible for the implementation of disaster risk reduction in MLM. And three sets of focus group interviews were also conducted with community members from the affected areas. The results of the interviews conducted with the ward councillors will be presented concurrently with that of the focus groups, followed by the results of the interviews with the senior disaster official and lastly, senior water official.

5.5.1 Interviews with ward councillors and community members

A total of six ward councillors, whose wards were affected by sinkholes, and three focus-groups of community members (ten per group) were interviewed. An overwhelming majority of 100% (N=6) of councillors indicated that the community members in their wards were aware of the formation of sinkholes. However, a shocking 49.98% (N=3) indicated that the community members in their wards did not know what caused / contributed to the formation of sinkholes; 33.32% (N=2)

indicated that community members knew the causes of sinkholes; and 16.66% (N=1) indicated that some members in the ward knew while others didn't.

By contrast, the focus group interviews revealed that the majority (25 out of 30 participants) of community members were aware of the causes or factors contributing to the formation of sinkholes in their area. It can therefore be argued that there is a lack of information sharing / communication between ward councillors and community members in certain wards. This is supported by the comment made by a focus group participant that "there are no community discussion forums regarding sinkholes / dolomite".

As stated earlier in the literature review, disaster risk can be reduced if the nature and causes of hazards are identified and their impact is understood (Carreno *et al.*, 2007; Perez-Lugo; 2001; Forbes-Biggs, 2011:11). In this regard, 83.3% (N=5) of ward councillors indicated that the occurrence of sinkholes in their communities pose risk to the houses (cracking walls), whilst 16.66% (N=1) were not sure of the risks that sinkholes posed to their community. In support to 83.3% response by ward councillors, 27 out 30 community members also indicated that the development of sinkholes is a hazard to houses. Moreover, the children like to play in shallow sinkholes and they may be at risk should the hole sink further. It is evident that the community members are aware of the formation and impacts of sinkholes in their area but there are no community discussion forums where information can be shared with various role-players in the area. A sinkhole risk reduction committee can provide a useful platform to facilitate the community discussion forums (between disaster officials, ward councillors and community members) in order to raise more awareness about sinkhole risk reduction. If people are informed about the nature of hazards and the measures they can adopt to minimise their vulnerability, they would be better equipped to deal with the risks (Carreno *et al.*, 2007; Perez-Lugo; 2001; Forbes-Biggs, 2011:11).

An overwhelming majority of 100% (N=6) ward councillors as well as 20 out of 30 community members indicated that the government and mines should be responsible for rehabilitating the damages caused by sinkholes in their communities. This response is supported by various legal frameworks discussed in chapter two (2).Specifically, the HFA indicates that the state (and by inference any of its sub-

levels of governance such as MLM*)* is primarily responsible for protecting people, infrastructure, economic, and social assets from the impacts of hazards (UN/ISDR, 2004:29; UN, 2004; Van Niekerk & Botha, 2013: 2). Also, section 43 of the Disaster Management Act indicates that district municipalities should consult with local municipalities regarding the establishment and management of disaster risk management structures, including disaster management centres, frameworks and advisory forums. Furthermore, section 2 of the NEMA indicates that the cost of remedying the environmental damage should be paid by those who are responsible for harming it (the environment). In addition, Section 39 of the MPDRA requires mining permit holders to develop an environmental management plan which outlines the baseline information for the affected environment, remedial measures, and environmental management objectives. It can therefore be argued that the MLM (custodian) and mines (that contribute to the formation of sinkholes through dewatering of dolomitic aquifers) should work together to reduce the risks associated with sinkholes as well as rehabilitate the sinkholes that have already developed in communities. MLM and local mines should establish a memorandum of understanding (MoU) to jointly fund the sinkhole awareness campaigns and rehabilitation process.

66.64% (N=4) of ward councillors suggested that in order to reduce the probability of sinkhole formation, there has to be a proper maintenance of water and sanitation facilities and members of the community should report leaking pipes on time. While, 16.66% (N=1) of ward councillors indicated that the whole area (MLM) should be assessed and where potential sinkholes are identified, the area should be filled. Another 16.66% (N=1) could not elaborate on any possible ways to reduce the possibility of sinkhole formation. Community members (26 out of 30) further indicated that faster response to water and sewage / sanitation leakages, installation of tarred roads and storm water drainage systems, as well as effective processes of regulating informal settlements could also help to reduce the formation of sinkholes.

The HFA's priority for action one (1) as well as NDMF's KPA 1 emphasises the importance of establishing institutional support for implementing disaster risk reduction strategies. Therefore, it can be argued that in order to reduce the risk of sinkholes forming in MLM, there must be structures / committees in which the senior

disaster and water officials as well as other role-players deliberate on aspects of sinkhole risk reduction to increase the effectiveness of existing approaches and avoid duplication of processes.

Furthermore, the establishment of community discussion forums (including disaster officials, ward councillors and community members) will play a critical role in ensuring that the views of the community are taken into consideration during the disaster risk planning process. In other words, discussion forums can provide a mechanism by which communities can directly communicate significant detrition of water/ sewerage infrastructure to councillors and officials.

The overall responses revealed that community members are aware of the formation and impacts of sinkholes in their area but there are no community discussion forums for continued sharing of information. Additionally, the findings also highlighted that the occurrence of sinkholes was considered a potential threat to houses and the community in general (children playing in shallow sinkholes). It can be argued that sinkholes have an adverse impact on the social-economic development of the MLM, as local houses lose value due to the at-risk status of the area. Besides the danger to existing infrastructure, the area experience no further structural development due to the inherent threat of sinkholes. Furthermore, sinkholes also affects the transport of goods and people to and from MLM due to temporary road closures. The next section will discuss the responses of ward councillors and community members in line with the HFA's priorities for action.

5.5.1.1 Priority for action 1 - Make DRR a priority

The role of local government in institutionalising disaster risk reduction is vital because it is the unit where practical activities such as land use practices can be regulated and safer construction methods can be promoted and enforced (Ahrens &Rudolph, 2006; Burby *et al.* 2007; Suntanta *et al.* 2006). The establishment of disaster risk management structures at local level is essential to ensure that strategies, policies and projects are implemented in such a way that the impacts of hazards can be reduced in order to establish disaster-resilient communities. A majority, 83.3% (N=5), of ward councillors reported that they participated in the development of the MLM's strategy to reduce the risk caused by the formation of

sinkholes through the forum established at district level. Whilst 16.66% (N=1) was unable to answer the question due to lack of information. However, 49.98% (N=3) of ward councillors indicated that the MLM does not have a committee which is specifically tasked with addressing sinkhole-related issues. In support, the community members (20 out of 30) also indicated that they were unaware of such a committee. Furthermore, 33.3% (N=2) of councillors were uncertain regarding the existence of such a committee. Another, 16.66% (N=1) indicated the existence of a committee, although she was not a member.

In light of the above, it can be argued that the implementation of sinkhole risk reduction strategy developed by the district municipality will be adversely affected by the lack of institutional support at local municipal level (the MLM). Therefore, the establishment of a disaster risk management committee at MLM will provide the institutional support for the implementation of sinkhole risk reduction initiatives.

66.64% (N=4) reported that the MLM does not provide ward councillors with training in sinkhole risk reduction. In addition, the community members (30 out of 30) also indicated that training was not provided to the community. However, 33.3% of councillors (N=2) indicated that training was provided, but not on regular basis. The inconsistency in responses could be caused by ineffective communication between the municipal official, ward councillors and communities, because information on training opportunities did not possibly reach other ward councillors or community members. In other words, some ward councillors may not have access to information and thus are unable to share with the community.

As already indicated in the literature review, the impacts of hazards can be reduced by equipping communities with the knowledge and capacity to be prepared or to respond and manage disasters effectively (Tierney *et al.*, 2001; Christoplos, 2001; Joyce, 2011; Chagutah, 2009). In this light, education (formal and informal) can be used to reinforce a culture of safety (resilience) towards risks posed by sinkholes.

5.5.1.2 Priority for action 2 - know the risk and take action

Risk assessment can be used as a tool to determine the nature and extent of risk by analysing potential hazards and evaluating existing conditions of vulnerability that

could pose a potential threat or harm to people, property, environment and the livelihoods on which they depend. In this light, 66.64% (N=4) of ward councillors indicated that the MLM does not conduct regular sinkhole risk assessments in the local community. While, 16.66% (N=1) could not respond due to lack of information and another 16.66% (N=1) indicated that regular assessments were conducted.

The community members (19 out of 30) indicated that the MLM does not conduct regular risk assessments, but one member indicated that a private organisation had once been contracted by the municipality to conduct risk assessments, but feedback was still awaited. The location of the Disaster Management Centre – approximately 50 kilometres away, in Randfontein – and lack of institutional support at the MLM affects the implementation of risk reduction initiatives such as risk assessments, awareness campaigns (information sharing), early warning systems, and disaster preparedness. As a result, it led to the adoption of a responsive approach to the management of sinkholes and exacerbates the risk.

As indicated in the literature, risk assessment requires a continuous monitoring of hazardous events, particularly those that are dynamic in nature (Basher, 2006: 2168; Perez-Lugo; 2001; Poolman, 2011: 12; Forbes-Biggs, 2011: 13). As a result, it assists in supporting regular reviews and re-assessment of hazards, exposure, and vulnerability as well as improving the understanding of evolving risk landscape and risk knowledge as a result of new data. The information acquired via sinkhole risk assessments can be used for public awareness programmes with the intention of changing behaviours so that communities can be more resilient to hazards such as sinkholes (Chagutah, 2009: 116; Poolman, 2011: 12; Forbes-Biggs, 2011: 13).

83.3% (N=5) of the ward councillors indicated that the MLM does not have an early warning system for sinkholes, while16.66% (N=1) could not respond due to lack of information. In addition, 21 out of 30 community members reiterated that the municipality did not have an early warning system and followed a responsive approach. In this light, it can be argued that the lack of regular sinkhole risk assessments in the MLM has contributed to the absence of sinkhole early warning system because information on hazards and vulnerabilities (obtained via risk assessments) is not readily available to set priorities. Thus the absence of regular

sinkhole risk assessments exacerbates the vulnerability of MLM community to sinkholes because they are not informed about early warning signs.

5.5.1.3 Priority for action 3 - build understanding and awareness

Risk can be reduced if people are informed and know how to act during a disaster (Chagutah, 2009: 116; Poolman, 2011: 12). In this regard, 83.3% (N=5) of ward councillors indicated that the MLM does not conduct public awareness campaigns to inform the local communities about the sinkhole risk reduction actions. While, 16.66% (N=1) was uncertain about the existence of sinkhole public awareness campaigns due to lack of information. Furthermore, the community members (29 out of 30) also confirmed that awareness campaigns were not conducted. In this light it can be argued that the lack of risk assessments contributed to the absence of awareness campaigns, which exacerbate the risk towards sinkholes due to lack of risk reduction information.

66.64% (N=4) of ward councillors indicated that the sinkholes risk reduction was not incorporated as part of the local school curriculum, while 33.3% (N=2) were uncertain if sinkholes risk reduction was part of the local school curriculum. And, the community members (23 out of 30) confirmed the absence of sinkhole risk reduction as part of the local school curriculum. In support, one participant was a member of a local school's governing body, and stated that such an approach would not be supported as it would be considered as a waste of time. As indicated in the literature, integrating sinkhole risk reduction lessons into the curricula of local schools can play a critical role to invest in children as the future generation, because it is believed that children and young people are more receptive to new information and can also act as channels to transfer knowledge to their families (Burby *et al.*, 2007: 256; Clerveaux & Spence, 2009: 209). The establishment of community discussion forums can serve as a platform to elaborate, amongst others, on the importance of integrating sinkhole risk reduction lessons in the curricula of local schools.

5.5.1.4 Priority for action 4 - reduce risk factors

Disaster risks relating to the changing social, environmental conditions, land use, and the impact of hazards associated with geological events, can be addressed during sector development planning and programmes as well as in post-disaster situations (Sakai *et al.*, 1999; UN, 2004). Thus, to reduce the underlying risk factors, structural and non-structural prevention and mitigation measures must be implemented. This means anticipating potential sources of risk by putting into practice procedures and other measures to either avoid hazards or reduce the economic, social and environmental impacts through corrective interventions (Carreno *et al.*, 2006; Sutanta *et al.* 2006: 344; UN, 2004). In this light, all ward councillors (100% (N=6)), indicated that sinkhole risk reduction is incorporated into land use planning in the MLM, because all low cost houses being erected had running water, flushing toilets, and dolomite-compliant foundation. In support, (27 out of 30) community members confirmed this by adding that houses in the new settlement (Extension 2) were fitted with different sanitation pipes. Apparently the foundations were also built according to a new, unique method and, lastly, a storm water drainage system was installed.

All 6 ward councillors highlighted the MLM does not have a system to regulate the erection of informal settlements in its area of jurisdiction. The community members (25 out of 30) also confirmed this response and one member further indicated that “the increasing number of shacks in the community was a clear indication of the absence of a system to regulate the informal settlement”. In this light, it can be argued that the MLM does not have an effective land use strategy because it fails to combat further erection of informal settlements. Consequently, the formation of sinkholes in the MLM will likely continue, as the communal taps in informal settlements cause excessive water seepage if not properly monitored and this remains a critical challenge. It is, therefore, critical that the MLM revise its land use strategy to improve the regulation of informal settlements in order to reduce the risk of sinkhole formation.

5.5.1.5 Priority for action 5 - be prepared and ready to act

No matter how well a community plans to prevent disasters, there will always be a chance that a disaster will take place (Tierney *et al.*, 2001; Christoplos, 2001; Joyce, 2011; Chagutah, 2009). Although not all natural hazards can be prevented from occurring, but their impact can be reduced by developing and implementing an integrated policy that focuses on effective response to disasters and post-disaster recovery and rehabilitation. In this light, 49.98% (N=3) of ward councillors indicated that the MLM does not have a sinkhole-formation preparedness plan in place. This response was also supported by the community members (20 out of 30). One participant mentioned that officials take long to respond to the reported signs of sinkhole formation, which increases the risks to people and infrastructure.

Interestingly, another 49.98% (N=3) of ward councillors indicated that the municipality does have a preparedness plan in place. It can be argued that if the plan does indeed exist it is not implemented, because its outcomes are not visible to some ward councillors and community members.

49.98% (N=3) of ward councillors reported that the MLM does not have a sinkhole recovery strategy designed to reduce the impacts of future sinkhole formation. Another 49.98% (N=3) indicated that the municipality does have a strategy to reduce the impacts of future sinkhole formation. Furthermore, the community members (30 out of 30) could not reply due to lack of information from the municipal officials. It can therefore be argued that if the strategy does exist, it is not accessible to some ward councillors and not shared with the community. Thus, reiterates the challenge of information sharing between the officials, ward councillors and the community.

5.5.2 Interview with the West Rand District Municipality disaster official responsible for disaster risk management at the MLM

The disaster official designated for the implementation of disaster risk reduction at MLM highlighted that the development of sinkholes in the MLM was as a result of the area been underlined by dolomite. Furthermore, in support to the information provided by the ward councillors (66.64%, N=4), the poor maintenance of water and sanitation infrastructure as well as failure by community members to report leakages

(water and sanitation pipes) in time had exacerbated the development of sinkholes in the area. It can, therefore, be argued that the failure of community members to report leakages in time emanates from the poor response by officials to attend the reported leakages. Therefore, public awareness campaigns and community discussion forums can be used as a platform to facilitate two-way communication about the risks caused by excessive water seepage in an area underlain by dolomite (like MLM).

The Senior Disaster Official also added that the occurrence of sinkholes on or next to roads affects the transportation of goods and people to and from MLM because the road will be closed due to its hazardous nature. In addition, closure of roads affects the economic development of the area because it delays the transportation and delivery of business goods.

5.5.2.1 PRA1 - make DRR a priority

According to the Senior Disaster Official, the West Rand District Municipality renders disaster management services to all municipalities within its district (Merafong, Westonaria, Mogale City and Randfontein). The representatives of various municipal departments, councillors, and ward councillors serve on the district disaster management advisory forum. This implies that the municipalities within the West Rand District do not have disaster management centres and therefore depend on the district to provide disaster management services. Therefore, the establishment of a dolomite committee at the MLM will provide institutional support for the implementation of the WRDM risk reduction initiatives. Furthermore, community discussion forums will ensure that the views of the community are taken into consideration during the WRDM dolomite risk-reduction planning.

The Senior Disaster Official highlighted that the West Rand District Municipality does not have a committee constitutes to address sinkhole-related matters. However, it does have a Disaster Management Advisory Forum which addresses all hazards within its vicinity. Given the extent of the risks and impact of sinkholes in MLM, it can be argued that the ineffectiveness in managing sinkholes results from categorising sinkholes as part of a generic risk rather than a priority.

Furthermore, the district has never provided training which is specifically developed to reduce the risk of sinkholes. However, it has provided all the municipalities in its area with a dolomite risk strategy to effectively deal with sinkholes. Although the inefficiencies of this strategy were highlighted in the previous section, it can be argued that the success of such a dolomite risk reduction strategy could be jeopardised by the lack of knowledge regarding its implementation. The failure of municipalities like MLM to implement the dolomite risk reduction strategy can also be directly associated with the lack of training and, possibly, failure to consult with the community and other relevant stakeholders during the strategy development process and its implementation. In other words, the dolomite risk reduction strategy might be developed for all the municipalities in WRDM, but it still need to be tailored to meet the needs of the MLM communities.

5.5.2.2 PRA2 - know the risk and take action

Risk assessment entails systematic procedures that determine the nature and extent of hazards by analysing them and evaluate the conditions of vulnerability that can adversely affect people, property, livelihood and the environment (Basher, 2006: 2168; Perez-Lugo; 2001; Poolman, 2011: 12; Forbes-Biggs, 2011: 13). The results of risk assessment contribute to the development of risk mitigation measures (Basher, 2006: 2168; Perez-Lugo; 2001; Poolman, 2011: 12; Forbes-Biggs, 2011: 13). Contrary to the response provided by the Ward Councillors (66.64%, N=4) and community members (19 out of 30), the disaster official indicated that the volunteers from the district municipality are deployed to conduct regular risk assessments under the supervision of the senior disaster management official designated for MLM. With the exception of the assessments conducted by an external company that was contracted by the MLM, it can be argued that risk assessments (as mentioned by the official) was either not conducted, or conducted in such a way that both ward councillors and community members were completely unaware of any assessments being undertaken in their community. As a result, it is evident that the ineffectiveness of the WRDM in managing dolomite risk reduction in MLM could be rooted in the absence of a disaster risk assessment process.

5.5.2.3 PRA 3 - build understanding and awareness

The disaster management official indicated that awareness campaigns are conducted in order to urge community members to report any signs of sinkholes to the municipal offices or district disaster management centre. This response is, however, contrary to the information provided by the ward councillors (83.3%, N=5) as well as the community members (29 out of 30). It is evident that ward councillors and community members in the MLM were unaware of any awareness campaigns in their community, which could only mean that such campaigns were never conducted. This reflects a grey area in the management of dolomite between the WRDM and MLM in a sense that the dolomite risk reduction strategy might include component such as public awareness but due to lack of institutional support at local level (MLM), outputs are not visible to the community. Therefore, the establishment of a dolomite risk reduction committee at MLM can provide institutional support for the implementation of sinkhole risk reduction strategy in order to raise more awareness.

Furthermore, the disaster management official was unable to indicate whether sinkhole risk reduction was incorporated as part of local school curricula in MLM. In this light, it can therefore be argued that the abovementioned response supports the information provided by ward councillors (66.64%, N=4) and community members (23 out of 30), which indicated that sinkhole risk reduction was not incorporated as part of the local school curriculum. The establishment of community discussion forums can serve as a platform to elaborate on the importance of integrating sinkhole risk reduction into the curricula of local schools.

5.5.2.4 PRA 4 - reduce risk factors

The disaster management official reported that the MLM utilises a dolomite risk reduction strategy in its land use planning process. This response confirmed the information provided by ward councillors (100%, N=6) as well as community members (25 out of 30) regarding the implementation of dolomite risk strategy during the land use planning process at MLM. However, the disaster management official was unable to respond whether the MLM has a system to regulate the erection of informal settlements in its area. The uncertainty of the disaster management official

correlates with the response provided by the ward councillors (100%, N=6) and community members, which indicated that the MLM does not have a system for regulating the erection of informal settlements in its area of jurisdiction. As a result, it can be argued that the dolomite land use strategy is no effective, since it does not regulate the erection of informal settlements in all areas. Therefore, it is critical that the land use strategy of the MLM should be revised to effectively regulate the erection of informal settlements in order to reduce the risk of sinkholes.

5.5.2.5 PRA 5 - be prepared and ready to act

The disaster management official indicated that the district municipality has a disaster preparedness strategy in place, which functions as follows:

- During working hours, the disaster management official is notified of all reported sinkholes that require risk assessment.
- After working hours, sinkholes are reported via the 107 Centre which is situated at the district municipality in Randfontein. The procedure for responding to a reported sinkhole is as follows:
    - A sinkhole is reported to the 107 Centre
    - The 107 Centre informs the disaster official, who then has to conduct the assessments and inform the Municipal Civil Engineering Department
    - The Municipal Civil Engineering Department then contacts the council of geo-science officials to conduct scientific assessments.

It is critical to indicate that the reporting of sinkholes via the 107 Centre is a long process, as the 107 Centre has to inform the disaster official, who has to inform the municipal civil engineering department. The civil engineering department has to inform the geo-science official to conduct the assessment. This extended communication process to the Geo-Science Council (to assess the sinkhole and provide rehabilitation), slows down the response process and escalates the sinkhole risk. This is supported by a comment made by one participant that the officials take long to respond to reported signs of sinkhole formation. As a result, the risk to people and houses increases and this reiterates the point that the municipality is following a responsive approach to manage sinkholes.

The disaster official was unable to respond if MLM has a sinkhole recovery strategy designed to reduce the impacts of future sinkhole formation. In support to the response (49.98% (N=3) provided by the ward councillors (that MLM does not have a sinkhole recovery strategy) and community members (30 out of 30), the disaster official was unable to respond whether the MLM has a sinkhole recovery strategy designed to reduce the impacts of future sinkhole formation. It can be argued that the uncertainty of the disaster official regarding the existence of sinkholes recovery strategy to reduce the impacts of future sinkholes in MLM indicates the absence of such a strategy because the official would be aware of its existence as it is a disaster risk reduction function. The absence of a sinkhole recovery strategy increases the susceptibility of the community to the impact of future sinkholes.

5.5.3 Interview with senior official: Water and Sanitation Department

The following section will present the results of the interview with the senior official at the Water and Sanitation Department in line with the HFA priorities for action.

5.5.3.1 PRA1 - Make DRR a priority

The Senior Official at Water and Sanitation Department reported that a telemetry meter system had been installed in all water reservoirs to monitor the quantity of bulk water received and compare it with the quantity of water used (and paid for) by the community. The unaccounted water was considered as a sign of water leakage on the reticulation system or in the reservoir itself. Also, if the quantity of bulk water received and water used by the community do not correlate, Water and Sanitation employees are deployed to search for the leaking pipe, if it had not been reported, and repair it.

5.5.3.2 PRA2 - know the risk and take action

According to the Senior Official at Water and Sanitation Department, the department was aware that leaking pipes contribute to the formation of sinkholes. As a result, the department set itself a goal of attending and fixing the leaking water and sanitation pipes within eight (8) hours of being notified as opposed to the national requirement

of attending the leakage within 8 hours and repairing it within 12 hours. It can be argued that the risk of sinkholes formation can be reduced if community members are encouraged, through awareness campaigns and community discuss forum, to report leakages as soon as possible.

5.5.3.3 PRA 3 - build understanding and awareness

The official reported that the department was facing a challenge of community members not reporting the leakages in time. Therefore, the department was planning to conduct an awareness campaign in the future to inform the community about the importance of reporting water or sewage leakages in time to reduce the possibility of sinkhole formation. In this regard, community discussion forums can serve as a platform for raising awareness and encouraging the community to report leakages in time.

5.5.3.4 PRA 4 - reduce risk factors

According to the Senior Official (Water & Sanitation), in order to provide a secure dolomite-compliant water and sanitation infrastructure in MLM, the department has set itself a goal to fix all leaking pipes within 8 hours of receiving a notification. In addition, broken asbestos pipes were replaced by uPVC (Unplasticised Polyvinyl Chloride) / HDPE (High-Density Polyethylene) pipes, which are able to withstand the shock of collapsing ground for a longer period of time.

In light of the response provided by the Senior Official (Water & Sanitation), it can be argued that the department is following a responsive approach by depending entirely on the community to report the leakages before fixing or replacing the pipes. A proactive approach where the department keeps record of the lifespan of water and sanitation infrastructure and replaces them periodically, can contribute to the reduction of excessive water seepage from leaking pipes.

5.6 Conclusion

This chapter presented the empirical research, findings and analysis of the strategies implemented by MLM to deal with sinkholes. The research sample was divided into four groups: ward councillors, senior officials at Disaster Management and the Department of Water and Sanitation, as well as community members.

Firstly, the results of the interviews conducted with the ward councillors and community members revealed that the MLM does not have a committee which is specifically mandated to deal with sinkholes, even though it is prone to the development of sinkholes. The MLM also does not provide training or awareness on sinkhole risk reduction to the ward councillors and the community as a whole, and as a result exacerbates the risk to sinkholes due to lack of risk reduction knowledge and capacity. Furthermore, MLM does not conduct regular sinkhole risk assessments in the community, and the community was not involved in the assessment process that was conducted in the past (which raises questions to the validity and implementation of any existing strategy). The MLM also has no sinkhole early warning system or sinkhole preparedness plan in place, which makes the community even more vulnerable to the impacts of sinkholes due to the lack of knowledge and capacity to manage the risk effectively.

Secondly, the interview conducted with the senior official responsible for the implementation of disaster risk reduction at MLM revealed that the West Rand District Municipality renders disaster risk management services to the MLM (in other words, the MLM does not have a disaster management centre) despite the fact that the area is prone to the development of sinkholes because it is underlain by dolomite. The poor maintenance of water and sanitation infrastructure as well as the community not reporting leakages (water and sanitation pipes) in time has exacerbated the development of sinkholes in the area.

The occurrence of sinkholes on and next to the roads causes road closures, which affects the transportation of business goods and people to and from the MLM. Road closures affect economic development in the area because it delays the transportation of goods. Although the WRDM does not have a committee that

specifically addresses sinkhole-related matters, but it has a Disaster Management Advisory Forum which addresses all hazards (like sinkholes) in its vicinity.

The district has provided all the municipalities in its area with a dolomite risk reduction strategy to effectively deal with sinkholes, but it has never provided training on the implementation of the strategy. As a result, it can be argued that the success of this dolomite risk reduction strategy will be adversely affected by lack of knowledge regarding its implementation. Furthermore, failure of municipalities such as MLM to implement the dolomite risk reduction strategy can be directly associated with the lack of training.

In contrast to the response provided by ward councillors (66.64%, N=4) and community members (19 out of 30), the disaster management official indicated that volunteers from the district municipality are deployed to conduct regular risk assessments under the supervision of a senior disaster official designated for the MLM. It can be argued that risk assessment (as mentioned by the official) was either not conducted or conducted in such a way that both ward councillors and community members were unaware of any assessments being undertaken in their community. As a result, it is evident that the ineffectiveness of the WRDM in managing dolomite risk reduction in MLM could be rooted in the absence of a disaster risk assessment process.

The disaster official indicated that awareness campaigns were conducted in order to urge the community members to report the signs of sinkholes to the municipal offices or district disaster management centre. However, this response contradicted the information provided by ward councillors (83.3%, N=5) as well as community members (29 out of 30). Therefore, if ward councillors and community members were not aware of any awareness campaigns in their community, such campaigns were probably never conducted.

In support to the information provided by ward councillors (100%, N=6) and community members (25 out of 30), the disaster official also indicated that the MLM utilises a dolomite risk reduction strategy in its land use planning process. However, the official was unable to respond whether the MLM had a system to regulate the erection of informal settlements in its area. This uncertainty by the disaster official

correlates with the response provided by the ward councillors (100%, N=6) and community members (indicating that the MLM does not have a system to regulate the erection of informal settlements in its area). Therefore, it is critical that the MLM land use strategy should be revised to effectively regulate the erection of informal settlements in order to reduce the risk of sinkhole formation.

Furthermore, in corroboration of the response by ward councillors (49.98%, N=3) and community members (30 out of 30), the disaster official was unable to respond whether the MLM has a sinkhole recovery strategy designed to reduce the impacts of future sinkhole formation. Therefore, the absence of a sinkhole recovery strategy increases the susceptibility of the community to the impacts of future sinkhole formation.

Finally, the results of the interview conducted with the senior official at the Department of Water and Sanitation revealed that the community did not report the water leakages in time (which increases the chances of sinkhole formation). However, it should be noted that the reporting system might be ineffective as a result of some community members not knowing how and where to report leakages. To address this, the department planned to launch an awareness campaign to inform the community about the importance of reporting water and sewage leakages in order to reduce the risk of sinkhole formation. Furthermore, in order to provide a secure dolomite compliance of water and sanitation infrastructure in MLM, the department has undertaken to fix leaking pipe within 8 hours after receiving notification (the national standard procedure aims to respond within 8 hours and repair the leakage within 12 hours). Furthermore, the broken water pipes were replaced by the uPVC (unplasticised polyvinyl chloride) / HDPE (High-Density Polyethylene) pipes which are able to withstand the shock of collapsing ground due to sinkholes.

The following chapter focuses on the conclusion of the study and presents the recommendations to guide the development of a sinkhole risk reduction strategy at MLM.

Chapter 6

Conclusion and recommendations

6.1 Introduction

This chapter presents a conclusion of the study that aimed to develop a sinkhole risk reduction strategy for the MLM. The findings discussed in the previous chapter are briefly presented. In particular, the empirical findings will be presented in a manner that answers the research questions to achieve the research objectives. This is followed by the recommendations that can be adopted to develop a sinkhole risk reduction strategy for the MLM. The following section will discuss the conclusion of the study based on the empirical findings.

6.2 Conclusion of the study

The empirical findings revealed that the development of sinkholes in the MLM was as a result of the area been underlined by dolomite. However, the poor maintenance of water and sanitation infrastructure as well as the community members not knowing where to report water and sanitation leakages has severely exacerbated the risk of sinkholes developing in the area.

The occurrence of sinkholes on the roads affects the transportation of business goods and people to and from MLM because of temporary closure of roads due to their hazardous nature. As a result, closure of roads affects the economic development because it delays the transportation business goods. Furthermore, the development of sinkholes restricts the types of business venture because most companies are not willing to structurally invest in the area due to its susceptibility to sinkholes. In addition, local houses have lost their market values due to the area been prone to the development of sinkholes.

The study also revealed that the Merafong Local Municipality does not have a disaster risk management centre or committee for dolomite risk management in its area. Therefore, the West Rand District Municipality renders disaster risk management services to MLM, although it raises questions regarding the efficacy of the service. The district municipality (located in Randfontein) has assigned an official to oversee the implementation of disaster risk management at the MLM. However,

the study raised serious questions about the management of the dolomite risk at the MLM. Very few councillors or members of the community have contact with the senior disaster management official, and almost no one has been involved in activities such as disaster risk assessment which are supposed to be coordinated by the official.

The district municipality does not have a committee that addresses sinkhole-related matters, but the district disaster risk management advisory forum deals with all hazards (including sinkholes) holistically. This is problematic because of the dolomite risk and threat it poses to the economic development of MLM, and thus, warrants the need for specialised and sustained attention.

Volunteers are deployed from the district under the supervision of a senior disaster management official to conduct sinkhole risk assessments at MLM. However, the response provided by the ward councillors and community members revealed that such assessments and awareness campaigns were not conducted in their area. It can, therefore, be argued that the location of the Disaster Management Centre (at Randfontein, approximately 50 kilometres away) and lack of institutional support (committee) at the MLM affects the implementation of risk reduction initiatives such as risk assessments, awareness campaigns, early warning systems, and the implementation of a disaster preparedness plan. As a result, it is evident that the ineffectiveness of the WRDM in managing the dolomite risk in MLM could be rooted in the lack of a community-based disaster risk assessment process.

It was claimed that the district municipality has provided all the municipalities in its area (including the MLM) with a dolomite risk-reduction strategy to effectively deal with sinkholes, but as indicated, no training was provided on the implementation of such a strategy. Therefore, it can be argued that the success of the dolomite risk reduction strategy provided by the district to the municipalities is adversely affected by the lack of knowledge or training regarding its implementation. Moreover, the failure of the municipalities such as MLM to implement the dolomite risk reduction strategy can be directly associated with the lack of training and lack of consultation with the community and other relevant stakeholders during the strategy development and implementation process. In this light, the establishment of a dolomite committee at the MLM would provide institutional support for training of officials (and if possible,

some community members) and facilitate community discussion forums to ensure a two-way communication process between the officials and community members.

It was claimed that, in order to ensure preparedness, the district municipality developed the following procedure to report sinkholes:

- During working hours, the disaster management official is notified of all reported sinkholes that require risk assessment.
- After working hours, sinkholes are reported via the 107 Centre which is situated at the district municipality in Randfontein. The procedure for responding to a reported sinkhole is as follows:
    - A sinkhole is reported to the 107 Centre
    - The 107 Centre informs the disaster official, who then has to conduct the assessments and inform the Municipal Civil Engineering Department
    - The Municipal Civil Engineering Department then contacts the council of geo-science officials to conduct scientific assessments.

It is critical to indicate that, despite the existence of a sinkhole preparedness plan and leakage reporting system at the district level, the empirical findings revealed that community members were unaware of where to report leakages (water and sanitation) due to the absence of awareness campaigns detailing the contact and procedures outlined above. This lack of awareness has resulted in continued water seepage from leaking pipes in dolomitic areas. Therefore, a pro-active approach such as the establishment of a dolomite committee at MLM and community discussion forums would provide institutional support for the implementation of risk reduction initiatives – such as regular awareness campaigns and risk assessments – in order to effectively design and revise the strategies to reduce the risk and mitigate the impact of sinkholes. The following section will look at crucial findings and recommendations as per the HFA.

The HFA was adopted as a theoretical argument of the study because it emphasises DRR. As indicated in chapter two, DRR is a framework that intends to systematically prevent as well as mitigate disaster risk regarding losses in lives and the socio-economic assets of communities. Therefore, the HFA is an appropriate framework to

be applied in MLM for sinkhole risk reduction because it follows a pro-active approach. It is evident from the empirical findings that the WRDM and MLM follows a reactive approach in managing sinkholes because assessments are only conducted when sinkholes are reported; awareness campaigns are conducted in a manner that is not visible or noticed by the community; and no training was provided on the implementation of risk reduction strategies. In this light, a pro-active approach could support the establishment of a dolomite risk management committee in order to provide institutional support for the implementation of risk assessments, awareness campaigns, preparedness plans, and recovery strategies to effectively manage the risk and mitigate the impacts of sinkholes.

Risk can be reduced if people are informed and know what to do during a disaster (Tierney *et al.*, 2001; Christoplos, 2001; Joyce, 2011; Chagutah, 2009). Therefore, community discussion forums can be used as platform to exchange information between officials and community members (regarding plans and envisaged sinkholes risk reduction strategies) in order to customise the strategies to meet local needs. In this light, community discussion forums can be used to encourage the community to participate in sinkhole risk reduction process by reporting leakages (water and sewage) as soon as possible, monitor communal taps in informal settlements, and attend awareness campaigns. The awareness campaigns can be used to enlighten and remind the community about the impacts of excessive water seepage in areas underlain by dolomite, as well as how and where to report the leakages in order to reduce the risk of sinkholes formations. Moreover, this could contribute to role clarification between responsible officials and community members in terms of reporting and response duties. The following section will provide the recommendations that can assist in developing a strategy for sinkhole risk management at MLM.

6.3 Recommendations

This section presents recommendations, in line with the HFA priorities for action that can assist in the development of a strategy for sinkhole risk reduction in Merafong Local Municipality.

6.3.1 Priority of action 1: Making DRR a priority

The empirical findings revealed that the MLM does not have a disaster management centre and as a result, the West Rand District Municipality renders disaster risk management services in the area. Lack of institutional support (committee) at the MLM affects the implementation of risk reduction initiatives such as risk assessments, awareness campaigns, early warning system, and disaster preparedness. Therefore, it is recommended that the MLM should establish a dolomite committee to provide institutional support for the implementation of sinkhole risk reduction plans and strategies. Stakeholders such the senior official in the Water and Sanitation Department, disaster management officials, ward councillors, community members, and representatives from the mines should serve on the committee to ensure a joint venture towards the management of sinkholes and avoid duplication of processes. In addition, community discussion forums should also be established to support and facilitate the exchange of information between the officials and community. As a result, this could address the challenge of sharing information with the community and also provide a platform for the community to actively participate in the sinkhole risk management process.

6.3.2 Priority for action 2: Know the risk and take action

The findings revealed that risk assessments are only conducted when sinkholes are reported; awareness campaigns are conducted in a manner that is not visible to the community; and no training is provided regarding the implementation of risk reduction strategies. Consequently, it can be said that a reactive approach is the norm with regard to managing the sinkhole risk reduction at MLM. It is therefore suggested that a new dolomite risk assessment should be carried out to revise the current dolomite risk reduction strategies for MLM. This new assessment should be more inclusive than those conducted in the past and also incorporate the inputs of ward councillors, communities and mining organisation operating in the area. Additionally, it is recommended that MLM (in consultation with the WRDM) should provide training to officials and community members who are involved in the execution of sinkhole risk reduction strategies.

6.3.3 Priority for action 3: Build understanding and awareness

As already indicated in the literature review, the impacts of hazards can be reduced by equipping communities at risk with the knowledge and capacity to be prepared or to respond and manage disasters effectively (Tierney *et al.*, 2001; Christoplos, 2001; Joyce, 2011; Chagutah, 2009). In this light, training should be based on the implementation of disaster risk reduction activities such as conducting risk assessments, awareness campaigns, developing early warning systems, as well as disaster preparedness and recovery plans. In other words, the training should equip the officials and involved community members with the skills to conduct regular sinkholes risk assessments and use the assessment information to develop awareness campaigns, early warning system, preparedness plans as well as recovery programmes.

6.3.4 Priority for action 4: Reduce the risk factors

Regular community-based sinkhole risk assessments could address the challenge revealed by the findings that the absence of awareness campaigns, early warning system and recovery plan was associated with the lack of risk assessment because information about the changing nature of risk was not readily available to develop effective risk reduction strategies. Therefore, it is recommended that new information on dolomite risk should be used for risk reduction strategies, and also be integrated with the IDP planning procedures of the municipality. This would ensure that dolomite risk reduction becomes an integral part of the economic development plan of the MLM.

6.3.5 Priority for action 5: Be prepared and ready to act

In light of the above, it can be argued that regular community-based risk assessments and the use of risk assessment information to develop and implement risk reduction strategies such as awareness campaigns, early warnings, and preparedness plan can result in a pro-active sinkhole risk management approach in MLM. The following section will present a conclusion of the study.

6.4 Conclusion

The objective of this study was to investigate the causes of sinkholes and the associated effect on the socio-economy of communities in Merafong Local Municipality. The empirical findings revealed that the development of sinkholes in the MLM was as a result of the area being underlain by dolomite. However, the poor maintenance of water and sanitation infrastructure as well as the community members being unaware of where to report leakages (water and sanitation pipes) has exacerbated the risk of sinkholes developing in the area.

The development of sinkholes on the roads affects the transportation of business goods and people to and from MLM because of temporary closure of roads due to their hazardous nature. As a result, closure of roads affects the economic development because it delays the transportation business goods. Furthermore, the development of sinkholes restricts the types of business ventures and most companies are not willing to structurally invest in the area due to its susceptibility to sinkholes. And, the local houses also lost their market values due to the area been prone to the development of sinkholes.

The findings also revealed that the MLM does not have a disaster risk management centre or committee in its area. However, the West Rand District Municipality has assigned an official from its office (located in Randfontein) to oversee the implementation of disaster risk management. As a result, the location of the Disaster Management Centre (at Randfontein, approximately 50 kilometres away) and lack of institutional support at MLM affects the implementation of risk reduction initiatives such as risk assessments, awareness campaigns, early warning system, and implementation of a disaster preparedness plan. As indicated, risk assessments are only conducted when sinkholes are reported, awareness campaigns are conducted in a manner that is not visible to the community, and no training was provided regarding the implementation of risk reduction strategies. In addition, the absence of early warning system and recovery plan was associated with the lack of regular risk assessment because information about the changing nature of risk was not readily available.

In light of the above challenges, it was firstly recommended that the MLM should establish a dolomite committee to provide institutional support for the implementation

of sinkhole risk reduction plans and strategies. Stakeholders such the senior official in the Water and Sanitation Department, senior Disaster Management Official, ward councillors and representatives from the mines should serve on that committee to ensure a joint venture towards the management of sinkholes and to avoid duplication of processes. In addition, community discussion forums should also be established to support and facilitate the exchange of information between officials and community members. As a result, this would address the challenge of sharing information with the community and create a platform for the community members to actively participate in the sinkhole risk management process.

Secondly, the MLM (in consultation with the WRDM) should provide training to officials and community members who are involved in the execution of sinkhole risk reduction strategies. Training should be based on the implementation of disaster risk reduction activities such as conducting risk assessments, awareness campaigns, developing early warning system, as well as disaster preparedness and recovery plans. As a result, regular community-based sinkhole risk assessments can address the challenge revealed by the findings that the absence of awareness campaigns, early warning system and recovery plan was associated with lack of risk assessment because information about the changing nature of risk was not readily available. As a result, this can lead to a pro-active management of sinkholes at MLM.

7 Bibliography

Ahrens, J and Rudolph, P. 2006. The Importance of Governance in Risk Reduction and Disaster Management. Journal of contingencies and crisis management. Vol. 14, No: 4.

Allen, K.M. 2006. Community-Based Disaster Preparedness and Climate Adaptation: Local Capacity-building In the Philippines. Disasters, 2006, 30(1): 81−101.

Basher, R. 2006. Global early warning systems for natural hazards: systematic and people-centred. Phil. Trans. R. Soc . Vol 364, pp 2167–2182.

Bates, F.L., Dynes, R.R. & Quarantelli, E.L. 1991. The importance of the social sciences to the International Decade of Natural Disaster Reduction. Disasters. 15. 3. 288-289.

Benson, C. & Twigg, J. 2007. Tools for Mainstreaming DRR. Guidance Notes for Development Organisations. ProVention Consortium Secretariat. www.proventionwebconsortium.org. Date of access: 24 July 2012.

Bell, J. 2005. Doing your research project: a guide for first-time researchers in education, health and social sciences. Maidenhead, England: Open University Press.

Berg, B.L. 2006. Qualitative research methods for the social sciences. United States of America: Progressive Publishing Alternatives.

Blaikie, P. Cannon, T. Davis, I, & Wisner, B. 1994. At risk: Natural hazards, people's vulnerability, and disasters. New York: Routledge.

Blaikie, N. 2000. Designing social research. Blackwell Publishing Ltd. Pp 338.

Blaxter, L., Hughes, C., & Tight, M. 2010. How to research 4th ed. Glasgow, United Kingdom: Bell and Bain Ltd.

Bless, C and Higson-Smith, C. 1995. Fundamentals of social research methods: An African perspective. 2ed. Pp 164.

Bless, C., Higdon-Smith, C. & Kagee, A. 2006. Fundamentals of social research methods: An African perspective. Juta. 4ed. Pp.190.

Boeije, H. 2010. Analysis in qualitative research. California: Sage Publications, Inc.

Booyens, S.A. 2008. Compliance with the codes of good practice and the Mining Charter by the South African mining industry: The role of the Department of Minerals and Energy. Potchefstroom: NWU. (Dissertation - M. Dev & Man.)

Bosher L.S. and Dainty A.R.J. 2011. Disaster risk reduction and 'built-in' resilience: Towards overarching principles for construction practice', Disasters: The Journal of Disaster Studies, Policy and Management, Vol.35, No1, pp. 1-18.

Brazer, P.J. 2011. Institutional capacity of the South African Police Service for disaster risk reduction in the Dr Kenneth Kaunda District Municipality. Potchefstroom: NWU. (Mini-dissertation - M. Dev & Man.)

Burby, R.J., Beatley, T., Berke, P.R., Deyle, R.E., French, S.P., Godschalk, D.R., Kaiser, E.J., Kartez, J.D., , May, P.J., Olshansky, R., Paterson, R.G., Platt, R.G. 1999. Unleashing the Power of Planning to Create Disaster-Resistant Communities, Journal of the American Planning Association, Vol, 65, No: 3, pp 247-258.

Buttrick, D.B. & Calitz, F. 1995. Guidelines for the application of the method of scenario supposition risk evaluation technique for the assessment of the stability of sides underlain by dolomite. Pretoria: Council for Geosciences.

Buttrick, D.B. & Van Schalkwyk, A. 1995. The method of scenario supposition for stability evaluation of sites of dolomitic land in South Africa. *Journal of the South African Institution for of Civil engineers,* 37(4):9-14.

Buttrick, D. & Van Schalkwyk, A. 1998. Hazard and risk assessment for sinkhole formation on dolomite land in South Africa. *Journal of Environmental Geology*, 36:1-2.

Buttrick, D.B., Trollip, Y.G., Watermeyer, R.B., Pieterse, N.D. & Gerber, A. 2011. A performance based approach to dolomite risk management. *Environ Earth Sci*, 64: 1127–1138.

Carreno, M. L., Cardona, O.D., Barbat, A. H. 2007. A disaster risk management performance index. Nat Hazards, 41, pp 1–20.

Chagutah, T. 2009. Towards improved public awareness for climate related disaster risk reduction in South Africa: A Participatory Development Communication perspective. JÀMBÁ: Journal of Disaster Risk Studies, Vol. 2, No.2, pp 113 – 126.

Christoplos, I., Mitchell, J., Liljelund, A. 2006. Re-framing Risk: The Changing Context of Disaster Mitigation and Preparedness. Disasters, 2001, 25(3): 185–198.

Creswell, J. 2003. Research design: qualitative, quantitative & mixed methods approach. United States of America: Sage Publishers, Inc.

Creswell, J. 2006. Integrated qualitative and quantitative research: Epistemology, history, and designs. In J. Smart (Ed.), *Higher education: Handbook of theory and research* (Vol. 11, pp. 90–136). New York: Agathon Press.

Clerveaux, V. and Spence, B. 2009. The Communication of Disaster Information and Knowledge to Children Using Game Technique: The Disaster Awareness Game (DAG). Int. J. Environ. Res.,Vol 3 No 2 :209-222.

Coetzee, C. & van Niekerk, D. 2013. Towards a disaster risk assessment methodology for communities underlain by dolomite. *Disaster Prevention and Management*. Vol. 22 No. 4, 2013, pp. 351-365.

Comfort, L., Wisner, B., Cuter, S., Pulwarty, R., Hewitt, K., Oliversmith, A., Wiener, J., Fordham, M., Peacock, W. & Krimgold, F. 1999. reframing disaster policy: The global evolution of vulnerable communities.

Dlamini, P.P. 2011. Evaluation the implementation of the Hyogo Framework for Action in the Kabokweni Location: View from the frontline perspective. Potchefstroom: NWU. (Mini-dissertation - M. Dev & Man.)

Forbes-Biggs, K. 2011. Disaster risk assessments and analysis. http://acds.co.za/index.php?page=usaid-project . Date accessed: 20 June 2013.

Fourie, K. 2011.Building a Culture of Safety: The nature of communication between the Maquassi Hills Fire Services and the community. Potchefstroom: NWU. (Mini-dissertation - M. Dev & Man.).

Greef, M. 2007. Information collection: Interviewing. (*In* De Vos, A. S., Strydom, H., Fouché, C. B. & Delport, C. S. L. Research at grass roots: For the social sciences and human service professions. Pretoria: Van Schaik. Chapter 20.).

Greener, I. 2011. Designing social research: a guide for the bewildered. London: Sage Publishers.

Guthrie, G. 2010. Basic research methods: an entry to social science research. London: Sage Publications.

Gutierrez, F. & Guerrero, J. 2008. A genetic classification of sinkholes illustrated from evaporate paleokarst exposures in Spain. *Environmental Geology*, 53:993-1006.

Hofstee, E. 2006. Extract from constructing a good dissertation: A practical guide to finishing a Master's, MBA or PhD on schedule. Www. exactica.co.za/dn/exatica-book-literature-review.pdf. Date accessed: 31 May 2013.

Housner, G.W. 1989. An international decade for natural disaster reduction, 1990-2000. Natural Hazards. 2. 45-75.

http://www.geoscience.org.za/images/stories/engineering/sinkhole3.jpg. Date of access: 5 January 2012.

International Strategy for Disaster Reduction (ISDR). 2004. Living with risk: A Global Review of Disaster Reduction Initiatives. Geneva: ISDR Secretariat. 386 p.

ISDR (International Strategy for Disaster Reduction). 2005. World Conference on Disaster Reduction: Hyogo Framework for Action 2005-2015. www.ifrc.org. Date accessed: 05 Feb 2012.

ISDR (International Strategy for Disaster Reduction). 2005. World Conference on Disaster Reduction: Hyogo Framework for Action 2005-2015. www.unisdr.org/hfa. Date accessed: 20 Feb 2012.

ISDR (International Strategy for Disaster Reduction) . 2005. World Conference on Disaster Reduction: Hyogo Framework for Action 2005-2015. www.unisdr.org/wcdr. Date accessed: 15 Feb 2012.

Izadkhah, Y. O., Hosseini., M. 2005. Towards resilient communities in developing countries through education of children for disaster preparedness. Int. J. Emergency Management, Vol. 2, No. 3.

Joyce, K.I. 2011. Public Awareness Campaigns as Effective Means to Reduce Disaster Risk: A Case Study of the Fire and Flood Campaign in the Western Cape. University of the Free State (Dissertation – Ma).

Kadzatsa, M. 2011. Critical Infrastructure. http://acds.co.za/index.php?page=usaid-project . Date accessed: 30 June 2013.

Jurad, J.F., Meeuvis, J. & Fourie, M. 2010. The threat of mine effluent to the UNESCO status of the Cradle of Humankind World Heritage Site. *The Journal for Transdisciplinary Research in Southern Africa*, 6(1):73-92.

Kirshner, J. 2011. "We are Gauteng people": Challenging the politics of xenophobia in Khutsong, South Africa. Paper prepared for the Politics and Sociology seminar, Rhodes University, February 23, 2011.

Laframboise, N., Loko, K. 2012. Natural Disasters: Mitigating Impact, Managing Risks. International Monetary Fund Working Paper. http://www.preventionweb.net/files/globalplatform/5198f60c0f21dNatural_Disasters_Mitigating_Impact,_Managing_Risks.pdf . Date accessed: 5 July 2013.

Langford, J. & McDonough, D. 2003. Focus Groups: Supporting effective product development. USA: Taylor & Francis Group.

La trobe. 2005. Mainstreaming Disaster Risk Management: A tool for development oranisations. Paper presented at the Integration Planning Against Risk (IPAR) series seminar in University College on 21 April 2005. London. http://www.swan.ac.uk/cds/research/ESRC.htm. Date of access: 15 July 2012.

Levy, J.K., Gopalakrishnan, C. 2010. A Policy-Focused Approach to Natural Hazards and Disasters—Towards Disaster Risk Reduction (DRR): Introduction to a Special Issue of the Journal of Natural Resources Policy Research, Journal of Natural Resources Policy Research, Vol 2, NO: 4, 317-323.

Li, G. & Zhou, W. 1999. Sinkholes in karst mining areas in China and some methods of prevention. *Engineering Geology*, 52:45 – 50.

Living with risk. 2004. A global review of disaster risk reduction initiatives. http://www.unisdr.org/files/657_lwr1.pdf. Date accessed: 27 July 2013.

Louw, A. 2012. Khutsong Safety Hazard. Carletonville Herald. 13 Sept. http://www.carletonvilleherald.com/articles/articledetails.aspx?id=16323. Date accessed: 3 May 2013.

Lunga, W. 2008. Community Based Disaster Risk Management Training. University of Zimbabwe, Harare. 33 p.

McENTIRE, D.A. 1997. Reflecting on the weaknesses of the international community during the IDNDR: some implications for research and its application. Disaster Prevention and Management. 6. 4. 221-233.

Mirza, M.MQ. 2003. Climate change and extreme weather events: can developing countries adapt?, *Climate Policy*, 3:3, 233-248.

Mitchell, T. 2003. An Operational Framework for Mainstreaming Disaster Risk Reduction. Benfield Hazard Research Centre. Disaster Studies Working Paper 8. London. University College. 29 p.

Mitchell, T., van Aalst, M. 2008. Convergence of Disaster Risk Reduction and Climate Change Adaptation. http://www.preventionweb.net/files/7853_ConvergenceofDRRandCCA1.pdf . Date accessed: 2 May 2013.

Monroe, J.S, Wicander, R. & Hazlitt, R. 2007. Physical geology: exploring the world. 6th ed. United States of America: Thomson Brooks/Cole.

Morgan, D.L. 1996. Focus Groups. Annual Review Sociology, 22:129-152.

Mouton, J. 1996. Understanding social research. Pretoria: Van Schaick Publishers.

Mussett, A.E. & Khan, M.A. 2000. Looking into the earth: an introduction to geological geophysics. Cambridge: Cambridge University Press.

Nel, T. & Haarhoff, J. 2011. The failure probability of welded steel pipelines in dolomitic areas. *Journal of the South African Institution of Civil Engineering*, 53(1):50 - 100

Neuman, W.L. 2006. Social research methods: Qualitative and Quantitative approaches. Pearson. Pp 592.

Ngcobo, T.A. 2006. The risk associated with mines in dolomitic compartments. *The Journal of South African Institute of Mining and Metallurgy*, vol. 106.

Olowu, D. 2010. The Hyogo Framework for Action and its implications for disaster management and reduction in Africa. *JÀMBÁ: Journal of Disaster Risk Studies*, 3(1): page numbers.

Phaiju , A., Bej , D., Pokheral, S., Dons, U. 2010. Establishing Community Based Early Warning System. www.preventionweb.net/english/professional/trainings-events/edu-materials/v.php?id=19893. Date of access: 30 October 2012.

Pearce, L. 2003. Disaster Management and Community Planning, and Public Participation: How to Achieve Sustainable Hazard Mitigation. Natural Hazards 28: 211–228.

Peatfield, D. 2003. Coal and coal preparation in South Africa – 2002 review. Paper presented at the 9th Australian coal preparation conference, Yeppon, 14–17 October 2003.

Pelling M., Özerdem A., Barakat S. 2002. The macro-economic impact of disasters. *Progress in Development Studies* 2, 4 (2002) pp. 283–305.

Perez-Lugo, M. 2001. The Mass Media and Disaster Awareness in Puerto Rico: A Case Study of the Floods in Barrio Tortugo. Organization & Environment, Vol. 14 No. 1, March 2001 55-73.

Poolman, E. 2011. Early warning system. http://acds.co.za/index.php?page=usaid-project . Date accessed: 25 June 2013.

Pope C., Mays, N. 2006. Qualitative research in health care. 3rd ed. Blackwell Publishing Ltd. United States of America.

Rambau, T.S., Beukes, L.D., Fraser, W., 2012, 'Disaster Risk Reduction through school learners' awareness and preparedness', Jàmbá: Journal of Disaster Risk Studies 4(1), Art. #61, 11 pages. Date accessed: 5 July 2013.

Richards, L. & Morse, J. M. 2007. Readme first for a user's guide to qualitative methods. Thousand Oaks, Calif.: SAGE.

Rosenthal, U. Comfort L. & Boin, A. 2001. Managing Crisis: A Global Perspective. USA: C.C. Thomas Publishers.

Sakai, S., Cuervo, J., Franklin, H., & Girot, P. 1999. Reducing vulnerability from natural hazards: Lessons learned from Hurricane Mitch. www.iadb.org/regions/re2/consultative_group/groups/ecology_workshop. Date of access. 21 September 2012.

Schoning, W.L. 1996. Distribution of sinkholes and dolines in the area south of Pretoria. Seminar on the development of dolomitic land, Pretoria, pp. 7/1-7/11.

Smith, K. 2002. Environmental Hazards: Assessing risk and reducing disaster. 3rd Edition. London: Routledge.

Sorensen J., Vedeld T., Haug M. 2006. Report on Natural hazards and disasters: Drawing on the international experiences from disaster reduction in developing countries. 16 January 2006.

South Africa. 2002. Disaster Management Act No. 57. (Regulation gazette no. 26228). Pretoria. Government Printers. 72 p.

South African Local Government Association. 2011. Disaster Risk Management Status Assessment at Municipalities in South Africa. http:// www.salga.org.za%2Fdocuments%2Fdownload%2Fapp%2Fwebroot%2Fassets%2Ffiles%2FResearch_Results%2FSalga_Draft_ReportFINAL_V1_3%2520(2).pdf . Date accessed: 4 May 2013.

Strahler, A. & Strahler, A. 2005. Physical geography: science and systems of the human environment. 3rd ed. United States of America: John Wiley & Sons, Inc.

Stromberg D. 2007. Natural Disasters, Economic Development, and Humanitarian Aid. *Journal of Economic Perspectives—Volume 21, Number 3 Summer 2007 Pages 199–222.*

Struwig, F.W. and Stead, G.B. 2001. Planning, designing and reporting research. Pearson Education South Africa. Pp 277.

Sutanta, H., Rajabifard, A., Bishop, I.D. 2009. An integrated approach for disaster risk reduction using spatial planning and SDI platform. Proceedings of the Surveying & Spatial Sciences Institute Biennial International Conference. Surveying & Spatial Sciences Institute, pp. 341-351.

Swart, C.J.U., James, A.R., Kleywegt, R.J. & Stoch, E.J. 2003. The future of the dolomitic springs after closure on the Far West Rand, Gauteng, RSA. *Environmental Geology*, 44:751-770.

Thomalla, F., Downing, T., Spanger-siegfried, E., Han, G., & Rockstrom, J. 2006. Reducing Hazard Vulnerability: Towards a common approach between Disaster Risk Reduction and Climate Change Adaptation. Blackwell Publishers. Oxford. 48 p.

Tierney, K.J., Lindell, M.K., Perry, R.W. 2001. Facing the unexpected: Disaster Preparedness & Response in the United States. Joseph Henry Press. United States of America.

Tong, A., Sainsbury, P. & Craig, J. 2007. Consolidated criteria for reporting qualitative research (COREQ): a 32-item checklist for interviews and focus groups. International Journal for Quality in Health Care, 19(6): 349 – 357. http://intqhc.oxfordjournals.org. Date accessed: 18 November 2013.

United Nations International Strategy for Disaster Reduction 2006. Developing Early Warning Systems: A Checklist. Third International Conference on Early Warning. From concept to Action. www.UN/ISDR-earlywarning.org. Date of access: 17 July 2012.

UNESCO. 2005. Natural Disaster Preparedness and Education for Sustainable Development. Bangkok: UNESCO Asia and Pacific Regional Bureau for Education.

United Nations International Strategy for Disaster Reduction. 2006. Four Elements of People Centred Early Warning Systems. Platform for the Promotion of Early Warning. www.UN/ISDR.org/ppew. Date of access: 16 July 2012.

United Nations International Strategy for Disaster Reduction. 2007. Guidelines: National Platforms for DRR. www.UN/ISDR.org.za. Date of access: 15 July 2012.

United Nations International Strategy for Disaster Reduction. 2007. Hyogo Framework For Action 2005-2015: Building the Resilience of Nations and Communities to Disasters. English-brochure, 2007 version. www.UN/ISDR.org/hfa. Date of access: 13 September 2012.

United Nations International Strategy for Disaster Reduction. 2007. Words into Action: A Guide for Implementing the Hyogo Framework, United Nations Secretariat of the International Strategy for Disaster Reduction (UN/ISDR), Geneva, Switzerland, pp. 4-5)

UN/ISDR. 2008. Disaster Preparedness for Effective Response: Guidance and Indicator Package for Implementing Priority Five of the Hyogo Framework. Geneva, Switzerland.

United Nation Development Programme. 2004. A global report for Reducing Disaster Risk: A challenge for development. www.undp.org/bcpr. Date of access: 4 February 2013.

United Nations International Strategy for Disaster Reduction (UN/ISDR). 2002. Living with risk: A global review of disaster reduction initiatives. Preliminary version. Geneva: ISDR Secretariat. www.UN/ISDR.org.za Date of access: 15 September 2012.

United Nations International Strategy for Disaster Reduction (UN/ISDR). 2005. HYOGO FRAMEOWRK FOR ACTION 2005 - 2015: Building the Resilience of Nations and Communities to Disasters. Extract from the Final Report of the World Conference on Disaster Reduction, 18 – 22 January 2005. www.unisdr.org/hfa/htm. Date of access: 12 September 2012.

United Nations International Strategy for Disaster Reduction. 2005. Strategic Directions for the ISDR System to Assist the Implementation of the Hyogo Framework for Action 2005-2015: Building the Resilience of Nations and Communities to Disasters. Document of the UN Inter-Agency Task Force on Disaster Reduction www.UN/ISDR.org.za. Date of access: 17 Septembe 2012.

UN/ISDR. 2011. Hyogo Framework for Action 2005 – 2015: Mid-Term Review 2010-2011. www. unisdr.org. Date of access: 1February 2013.

United Nations (UN). 2000a. General Assembly Resolution 541219. International Decade for Natural Disaster Reduction Successor Arrangements. 3 February. Geneva: UN.

United Nations (UN). 2005. Report on the World Conference on Disaster Reduction. Kobe, Hyogo, Japan, 18-22 January 2005. AlCONF.20616. 16 March 2005.

United Nations (UN). 2003. UN Millennium Development Goals (MDG). [Web: http://www.un.org.millenium goals Date of access: 16 February 2013.

United Nations (UN). 2005. Report on the World Conference on Disaster Reduction. Kobe, Hyogo, Japan, 18-22 January 2005. AlCONF.20616. 16 March 2005.

United Nations Inter-Agency Secretariat of the International Strategy for Disaster Reduction (UNISDR). 2004. The mission and objectives of the ISDR. [Web: http://ww.unisdr.or~/en~/abouist drlisdr-missionobiectives- enahtm]. Date of access: 22 January 2013.

United Nations Inter-Agency Secretariat of the International Strategy for Disaster Reduction (UNISDR). 2002. ISDR background paper for WSSD. Geneva: UN.

Van Eeden, E. 1997. So long, gold mines live industries? A case study of Carletonville's battle for economic survival. *South African Journal of Economic History*, 12(1-2):103-127.

Van Eeden, E.L. 2006. Some human actions in the destruction and construction of culture and nature – the Merafong region as a case study. *The Journal for Transdisciplinary Research in Southern Africa*, 2(2):409-430, December.

Van Eeden, E.L., De Villiers, B., Strydom, H. & Stoch, L. 2003. Effects of dewatering and sinkholes on people and environment – an analysis of the Carletonville area in Gauteng, South Africa. *The Journal for Historia* 48(1): 95-125, May.

Van Eeden, E.S., Liefferink, F. & Durand, J.F. 2009. Legal issues concerning mine closer and social responsibility on the West Rand. *The Journal for Transdisciplinary Research in Southern Africa*, 5(1):51-71.

Van niekerk, D. 2005. A Comprehensive Framework for Multi-Sphere DRR in South Africa. Potchefstroom: NWU. (Dissertation – D.Phil) 354 p.

Van niekerk, D. 2006. Disaster Risk Management in South Africa: The function and the activity – towards an integrated approach. *Journal for Political Science and Public Administration*. Politeia. Vol. 25 (2) p 95-115.

Van Niekerk, D., Coetzee, C. 2012. Chapter 17 African Experiences in Community-Based Disaster Risk Reduction: Community-Based Disaster Risk Reduction Community, Environment and Disaster Risk Management , Volume 10, Emerald Group Publishing Limited, pp.333-349.

Von Oelreich, E. 2011. In-depth study on the United Nations contribution to the implementation of the Hyogo Framework for Action. http://www.unisdr.org/we/inform/publications/27854. Date accessed: 3 May 2013.

Views from the Frontline. 2009. Clouds but little rain. http://www.preventionweb.net/files/globalplatform/VFLsummaryreport0609.pdf. Date accessed: 1 May 2013.

Visser, R. & van Niekerk, D. 2009. A funding model for disaster risk reduction in municipalities in South Africa. (Research report for the National Disaster Management Centre of South Africa, July 2009.) Potchefstroom: ACDS. 86 p.

Wamsler, C. Mainstreaming risk reduction in urban planning and housing: a challenge for international aid organisations. Disasters, Vol 30, N0 2: 151−177.

Watermeyer, R.B. 2001. Proposed method for dolomite land hazard and risk assessment in South Africa. *Journal of the South African Institute of Civil Engineering*, 43(2):27–36.

Watermeyer, R. B. 2001. Proposed method for dolomite land hazard and risk assessment in South Africa. *Journal of the South African Institute of Civil Engineering*, 44(3): 27 – 36.

Winde, F. & Stoch, E.J. Threats and opportunities for post-closure development in dolomitic gold mining areas of the West Rand and Far West Rand (South Africa). http:/ / www.wrc.org Date of access: 21 December 2010.

Wisker, G. 2001. The postgraduate research handbook. Palgrave. Pp 334.

Wisner, B. 2006. Let our children teach us: A review of the role of education and knowledge in disaster risk reduction. Books for change. India.

Wolmarans, J.F. 1996. Sinkhole and subsidences on the Far West Rand. Seminar on the development of dolomitic land, Pretoria, pp. 6/1-6/12.

World Meteorological Organization (WMO). 1997. Comprehensive Risk Assessment for Natural Hazards. WMO/TD No. 955. Geneva.

Yokohama Strategy and Plan of action for a Safer World. 1994. Guidelines for Natural Disaster Prevention, Preparedness and Mitigation. World Conference on Natural Disaster Reduction. Yokohama, Japan, 23-27 May.

Zhou, W. & Beck, F.B. Management and mitigation of sinkholes on karst lands: an overview of practical applications. *Environmental Geology*, 55:837–851.

Questionnaire for Ward Councilors

1. Are community members in your ward aware of the formation of sinkholes?
2. Do they know what causes / contribute to the formation of sinkholes?
3. What kind of risks do they think sinkholes will cause in their community?
4. How does the formation of sinkholes affect the economic development of the community?
5. Who do they think is responsible for dealing with the formation of sinkholes?
6. What do you think should be done to reduce the formation of sinkholes?
7. Do you think the community can play a role in the reduction of sinkhole formation? If yes, which role can the play?

PRA 1: Institutional arrangements

8. Do local community representatives participate in the development of the MLM strategy to reduce the risk caused by the formation of sinkholes?
9. Does the municipality have a committee to address the issues of sinkholes? And do ward councilors serve on that committee?
10. Does the MLM provide training in the sinkhole risk reduction to ward councilors?
11. Does the MLM incorporate sinkhole risk reduction in its development plans?

PRA 2: Assessment and monitoring

12. Does the MLM conduct regular sinkhole risk assessment in the local community?
13. Does the MLM have effective sinkhole early warning system in place?

PRA 3: Knowledge and Innovation

14. Are there public awareness initiatives to inform local communities about sinkholes risk reduction actions?
15. Is sinkhole risk reduction taught as part of local school curricula?

PRA 4: Underlying risk factors

16. Is sinkhole risk reduction incorporated into the MLM land use planning?
17. Does the MLM have a system to regulate the erection of informal settlement?

PRA 5: Preparedness and recovery

18. Does the MLM have sinkhole-formation preparedness plan in place?

19. Is there a sinkhole recovery strategy designed to reduce the impact of future sinkhole formation?

Questionnaire for senior official in Disaster Management Department at MLM

1. What are the causes of sinkholes in the MLM?
    a. Briefly elaborate on the history of sinkhole formation in the area?
2. How does sinkholes affect the economic developmentof the community?
3. Is there a system in place where community members can report to the local authority the possible signs of sinkhole formation? How does the system work?

PRA 1: Institutional arrangements

4. Does the MLM allow the affected role players to participate on the development of the strategy to reduce the risk of caused by formation of sinkholes? If yes, which role players are involved and in what way do they participate?
5. Does the municipality have a committee to address the issues of sinkholes? And which members serve on this committee?
6. Does the MLM provide training in sinkhole risk reduction? If yes, which members attend?
7. Is the sinkhole risk reduction incorporated into the MLM development plan?

PRA 2: Assessment and monitoring

8. Does the MLM have system in place to regularly monitor the formation of sinkholes?

    If yes how does the system operate?

    if no how does MLM deal with formation of sinkholes?

9. How frequent do you conduct dolomite risk assessments in MLM ?
    a. Which Role Players are involved in conducting this assessment?

PRA 3: Knowledge and Innovation

10. Are there initiatives in place to inform communities about the risk caused by the formation of sinkholes and how to combat the factors that contribute to the formation of sinkholes?
11. Is sinkhole risk reduction taught as part of local school curricula?

PRA 4: Underlying risk factors

10. Is sinkhole risk reduction incorporated into the MLM land use planning?
11. Does the MLM have a system to regulate the erection of informal settlement?

PRA 5: Preparedness and recovery

12. Does the MLM have a sinkhole preparedness plan in place? If yes, briefly elaborate the plan?
13. Does the MLM have a sinkhole recovery programme that is designed to reduce the impact of future sinkhole formation?

Questionnaire for senior official in Water and Sanitation Department at MLM

1. Are you aware of the dolomite challenge in the MLM?

   1.1 What kind of challenges does the dolomite bring to your department?

   1.2 And how do you deal / overcome those challenges?

2. Is there a system in place to categorise water and sanitation infrastructure (in terms of their years of installation) in the MLM?
3. Is there a system in place for monitoring the leakage of water and sanitation reticulation infrastructure? And how does it work?
4. How do you prioritise services towards the maintenance of water and sanitation reticulation system?
5. How long does it take to respond to a leaking pipe or resoviour?
6. Are there storm water drainage in all residential areas?
7. Are there initiatives in place to inform communities about the risk caused by formation sinkholes and how to combat the factors that contribute to the formation of sinkholes?
8. What does Water and Sanitation Department do to provide secure, dolomite compliant of water and sanitation infrastructure in the MLM?

Questionnaire for Focus Groups

10. Do you know what causes / contribute to the formation of sinkholes?
11. What kind of risks do you think sinkholes will cause / or has caused in your community?
12. How does the formation of sinkholes affect the economic development of the community?
13. Who do you think is responsible for dealing with the formation of sinkholes?
14. What do you think should be done to reduce the formation of sinkholes?
15. Do you think the community can play a role in the reduction of sinkhole formation? If yes, which role can the play?

PRA 1: Institutional arrangements

16. Does the municipality have a committee to address the issues of sinkholes? And do community members serve on that committee?

8. Does the MLM provide training in the sinkhole risk reduction to community?

8.1 Are you able to get information about sinkholes to from their councilors, or are they able to use the councilors as a direct channel to the municipality to inform the municipality about dolomite risk (just to test the relationship between community and councilors as this is an important arrangement that needs to work for DRR).

PRA 2: Assessment and monitoring

9. Does the MLM conduct regular sinkhole risk assessment in the local community?

10. Does the MLM have effective sinkhole early warning system in place?

PRA 3: Knowledge and Innovation

11. Are there public awareness initiatives to inform local communities about sinkholes risk reduction actions?

12. Is sinkhole risk reduction taught as part of local school curricula?

PRA 4: Underlying risk factors

13. Is sinkhole risk reduction incorporated into the MLM land use planning?

14. Does the MLM have a system to regulate the erection of informal settlement?

PRA 5: Preparedness and recovery

15. Does the MLM have sinkhole-formation preparedness plan in place?

15.1 (probing question: Were they part of the process in formulating this plan?)

16. Is there a sinkhole recovery strategy designed to reduce the impact of future sinkhole formation?