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GEOTECHNICAL CONDITIONS, COMMUNITY- BASED PRACTICES AND DEVELOPMENTS IN SLOVO PARK INFORMAL SETTLEMENT, JOHANNESBURG

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A research report submitted to the Faculty of Engineering and the Built Environment, University of the Witwatersrand, in fulfilment of the requirements for the degree of Masters of Built Environment in Housing.

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Declaration

I, the undersigned, hereby declare that the work contained in this thesis is my own original work and that I have not previously in its entirety or in part submitted it at any university for a degree.

Signature: .....

Date: .....May 25, 2018.....

Abstract

In recent years, authorities, experts and environmental agencies have had to deal with the challenge of considering dolomitic zones for the *in situ* upgrading of urban informal communities. South Africa appears to lead many regions globally in the management of developing construction methods on dolomitic terrains. The benefits of such expertise are, however, not yet visible in informal settlements. Intervention envisaged by the Constitution, various laws and regulations seem to have little effect. The challenge remains: the need to significantly improve the economic prospects and livelihoods of residents of informal settlements. Lack of such interventions is driving dangerous practices that exacerbate the development of dolomitic hazards, such as sinkholes.

The informal settlement of Slovo Park was selected for the study because it is built on dolomite and at present there are major on-going debates between the City of Johannesburg (CoJ) and the community around issues of residential upgrading in relation to possible geotechnical hazards materialising in this area. The aim of the study was to investigate and define human actions that can exacerbate the formation of sinkholes within this type of setting. This research also strives to illustrate the gap that exists between conventional geotechnical interventions, and the important key roles that informal communities could play in preparing for and mitigating dolomitic risks.

The study recommends the adoption of a Dolomite Risk Management protocol, as well as social awareness programmes, to inform residents of the negative impacts that socio-cultural and household practices and decisions can have on sinkholes creation.

Keywords: *Informal settlements, Sustainable human settlements, Dolomitic grounds, Hazard, Risk, Inherent risk, Disaster Risk Management*

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Acronyms/Abbreviations

ANC	African National Congress
BNG	Breaking New Ground
$Ca(HCO_3)_2$	Calcium hydrogen carbonate
$CaMg(CO_3)_2$	Dolomite
CoJ	City of Johannesburg
CUP	Cambridge University Press
CWP	Community Works Project
DHZ	Dolomite Hazard Zone
DHS	Department of Human Settlement
DRMP	Dolomite Risk Management Programme
EIA	Environmental Impact Assessment
GDC	Geotechnical Dolomitic Category
GPS	Geographical Positioning System
H_2CO_3	Carbonic acid
M	metre
M^2	metre square
MEC	Member of the Executive Council
$Mg(HCO_3)_2$	Magnesium hydrogen carbonate
NHBRC	National Home Builders Registration Council
NP	National Party
pH	Potential of Hydrogen
RDP	Reconstruction and Development Programme
RPT	Regional Professional Team
SANS	South African National Standards
SPCDF	Slovo Park Community Development Forum

UISP	Upgrading of Informal Settlements Programme
UN	United Nations
UNCHS	United Nations Centre for Human Settlements
USGS	United States Geological Survey
VIP	Ventilated Improved Pit-latrines
WAD	Weathered Altered Dolomite
WITS	University of the Witwatersrand

CHAPTER ONE

1.1 Introduction to the study

In South Africa, residential construction on soils with underlying soluble limestone or dolomite proves a challenge in bridging the housing deficit without disrupting the communities. This, to some extent, affects the *in situ* upgrading of informal settlements. Gauteng Province has the greatest prevalence of dolomite in the country. The province is constituted of more than 20 per cent of dolomitic lands (Buttrick *et al*., 2001). The densely populated dolomite zones in Gauteng are susceptible to abrupt, disastrous subsidences known as sinkholes. These disrupt developments and communities, lead to infrastructure damage and in some cases, even death (Bezuidenhout and Enslin, 1970; De Bruyn and Bell, 2001). While sinkholes may materialise without any warning, small-scale ground cavities, fractures in settlements' ground and in walls, and the crumbling of the foundations are usually the initial warning signs of the imminent development of large hollow gaps (Buttrick and Van Schalkwyk, 1998). This carries a potential risk to the environment and inhabitants that occupy such a space. Sinkholes pose further critical concerns, particularly in the planning of water bearing infrastructure, buildings, and roads. In such cases, special construction techniques, for example, approved dolomite soil mattresses, grouting, raft foundations, piles, and dynamic consolidations are used (Heath, personal communication, 18 August 2017).

This research aims to examine the notion that dolomite related risks are a growing problem and of late are increasingly induced by human behavioural practices within the Gauteng Province (Storie, 2016). Studies have estimated that in excess of a billion Rands have been lost in property damages, and at least 38 deaths have been documented in this region within the last six decades as a result of the formation of sinkholes (Oosthuizen and Richardson, 2011). Densification of informal residential developments contribute much to altering the way in which water naturally soaks into dolomitic ground systems, resulting in the occurrences of subsidence (Heath *et al*., 2007). While communities play a significant role in activating or exacerbating these occurrences, are they aware of how some of their daily social, cultural and household practices contribute directly to such hazards?

The informal settlement of Slovo Park in Soweto was selected for the study because it resides on dolomitic ground (Figure 1.1), and at present there are major on-going debates between the City of Johannesburg (CoJ) and the community through the High Court about residential development in

relation to possible sinkhole events. The area is now set for redevelopment in terms of *in situ* upgrading and the provision of basic services. The Slovo Park precinct will be used as a case study involving the local practices and understandings of the impact of these practices on dolomite.

The hypothesis I put forward is that the Slovo Park community may be unaware or not very knowledgeable of how sinkholes are activated, and which results in other detrimental effects that impact on their activities. Furthermore, even where the intentions are good, their coping mechanisms and interventions for mitigating and monitoring such incidents to prevent them from happening in their surroundings remain skewed in favour of the creation of more sinkholes. Since formal development have not materialised in Slovo Park, the study envisages that there are no municipal bulk or reticulation services. In the absence of these services, therefore, the research assumes that the community is inadvertently confronted with limitations brought about by a range of self-help modes relating to land use, effluent and waste management, and water supply and management. This re-emphasises the existence of dangerous practices that have negative impacts on dolomite, and that are largely and effectively ignored by the residents concerned. Finally, the study maintains that human behaviour, in addition to geotechnical interventions, might possibly have a significant impact on mitigating the risks of disaster on dolomitic grounds.

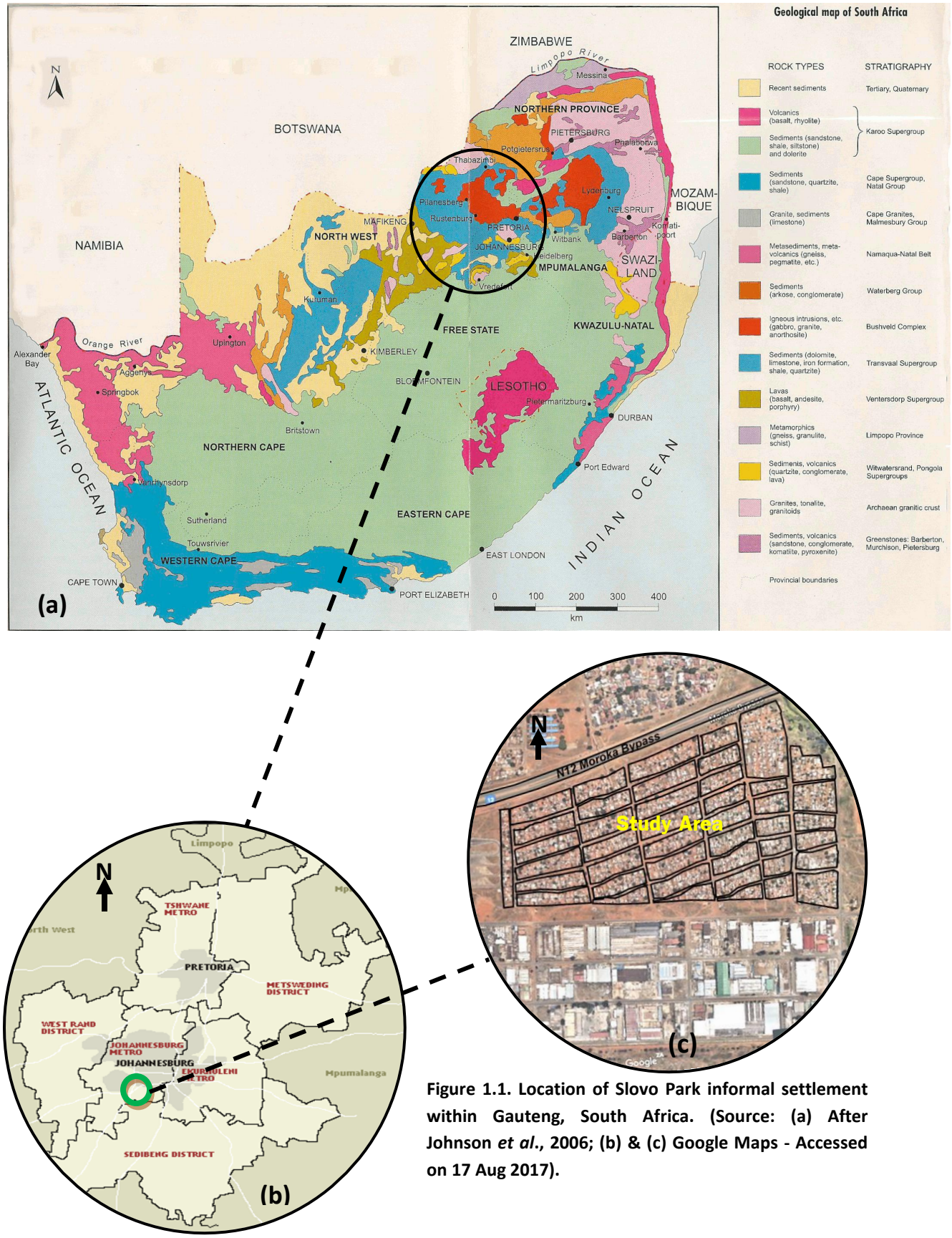

Figure 1.1. Location of Slovo Park informal settlement within Gauteng, South Africa. (Source: (a) After Johnson *et al.*, 2006; (b) & (c) Google Maps - Accessed on 17 Aug 2017).

1.2 Background to the problem statement

In 2004, the CoJ proposed the *in situ* upgrading of Slovo Park informal settlement with its 300 m^2 stands as one of its highest priorities in the Regional Professional Team's (RPT) programme. However, the preliminary risk assessments which were comprised of an Environmental Impact Assessment (EIA) and geotechnical investigations revealed the prevalence of dolomite in this area. Since in this context only a portion of the households can be redeveloped within the site, the remaining and qualifying households were to be resettled at an alternative site, known as Unaville, which is eleven kilometres away from Slovo Park (iNtatakusa Africa Feasibility Report, 2005). Unfortunately, it is unknown whether Unaville displays similar dolomite challenges, since the consideration of dolomite has to take cognisance of overburden of even up to 60 m.

Due to subsequent socio-spatial tensions triggered by the aforementioned recommendation, residents gathered insurgent, subversive forces to oppose this proposal and became resilient against relocation and disintegration of the strong social bonds formed in the process of informal settlement. This contestation was essentially stimulated by the following factors: 1) the community argued that the geotechnical findings compiled in an interim report by the previous consultant, Intraconsult Geotechnical Project, in 1990 were invalid and outdated; 2) in 2004, iNtatakusa Africa Consulting confirmed that this report was based on limited data, only focused on dolomite bedrock, and failed to integrate an evaluation of surface soil conditions. As a result, CoJ recommended further in-depth soil and dolomite investigations on the site to develop a proclamation rationale (iNtatakusa Africa Feasibility Report, 2005).

Interestingly, the redevelopment process for Slovo Park was reinitiated when the Johannesburg High Court gave an order to the CoJ on the 5th of April 2016 to upgrade this settlement in accordance with the Upgrading of Informal Settlements Programme (UISP) framework. The judgment, considering the constitutional right to adequate housing, underlined again that "the UISP applies to all informal settlements and that relocation be resorted to only after the possibility of upgrading has been investigated and this approach found to be unfeasible" (Zondo *et al.*, 2016). This led to the CoJ appointing a new consultant, Urban Dynamics, to do the planning (CoJ, 2017). This involved commissioning a geotechnical study. The consultant, among others, also had to evaluate the relevant research material available on this area, and fill in such gaps as what may have may have become apparent since the previous studies. The ruling by the court on the recommendations is not only

relevant to this research, it also provides a basis for this research, namely to explore the level of potential geotechnical risks that the area holds. In addition, the investigation had to establish how these risks may or may not affect the community and its development. It also had to determine what level of awareness on sinkholes and their formation mechanisms exist within the community.

1.3 Problem Statement

The Slovo Park informal settlement features diverse communities in its residential makeup, and displays one of the highest residential densities within the municipal boundaries of CoJ. The community encompasses 3 734 families on 1 469 informal residential stands, implying that there is more than one household unit per stand (CoJ, 2017). In accordance with NHBRC requirements, the community should be restructured into stands of 300 m^2 per household. In practice, this left 1 469 stands for feasible housing development on the available geologically safe site (*ibid*.). In the CoJ, the existing policies, standards and regulations with regard to the management of development on dolomite focus simply on the relocation of settlements and the application of geotechnical interventions. It completely overlooks the significant role that human behavioural considerations could play in potential hazard mitigation on the geologic terrain.

1.4 Rationale of the study

The concepts of anthropogenic hazards in dolomitic environments have been broadly and systematically studied and authors have produced extensive literature on the subject as reviewed in the subsequent chapter. However, the same cannot be said of informal settlements since human factors that trigger or induce sinkhole development in these types of settings are largely overlooked by the scientific and academic community and public domain, including government (Storie, 2016). A possible exception is cases of infrastructure development in South Africa. Relatively few research studies have been conducted on the matter. This challenge presents an opportunity to develop new thinking about the gap between geotechnical interventions, and the levels of risk linked to human behavioural actions that are inclined to induce the frequency of sinkholes.

This research on Slovo Park informal settlement is imperative for critically assessing human activities that may induce or cause the area's environment to become more susceptible to sinkhole hazards. Likewise, the study provides insights with regard to existing methods for determining the development of sinkholes through reviewing of existing literature, and how to mitigate sinkholes.

Many previous empirical studies undertaken in Slovo Park were highly technical and were carried out on being appointed as an engineering geologist by a prospective developer. There is a long history of research produced on Slovo Park post 1990, the year which marks the beginnings of Slovo Park informal settlement. Many of these studies are a challenge to rely on as they tend to dismiss the existence of possible subsurface cavities due to an increase in the human population. Therefore, human activities as relating to land and water use, as well as the expansion and transitioning of this settlement have led to a complex evolution of the dolomitic system.

This study seeks to provide a better understanding the challenges sinkholes pose for urban housing development, and for the community of Slovo Park. Taking into consideration that while sinkholes may occur naturally, given adequate time certain activating mechanisms may become present as a result of human activities, and such phenomena may be fast-tracked (USGS, n.d.).

1.5 Research Aim

The disastrous incidents of parts of the land sinking into the ground are at times led by human activities and water level changes in aquifers (Oosthuizen and Richardson, 2011). In general, such practices include using water taps for public ablutions without providing surface water drainage or extraction, the abstraction of groundwater, the use of pesticides and agrochemicals in urban farming, and the disposal of household waste-fills in already developed ground cavities within the surroundings of the area, which may influence the chemistry and dynamics of groundwater (Durand, 2007). Some cases have been noted in which community members use the cavities as sites for waste disposal. However, not only do these anthropogenic mechanisms pose serious risks as to activating ground subsidence, but they also hold critical implications for the preservation of water quality. The aim of the study is to investigate and define human actions that may exacerbate the formation of sinkholes in the Slovo Park precinct, paying special attention to social and cultural behavioural patterns.

Communities such as Slovo Park are poorly prepared to deal with the aftermath of subsidence and sinkhole events. This is mainly due to a lack of financial resources and/or insurance to rely on, and the level of knowledge in the community on how sinkholes are triggered, since these natural phenomena develop gradually over years. However, most important to this research is that human causes and activities such as, but not limited to, leaking water pipes and sewerage systems, often fast-track the timeframe of sinkhole manifestation to only a few seconds, hours or days depending

on the intensity applied by these factors (USGS, n.d.). Since most research revealed that three-quarters of these phenomena are triggered by human behavioural practices (Durand, 2007), it is imperative that these communities are made aware of the effects of leaking water pipes and ingress of water if sinkhole formation is to be prevented or mitigated. Developing sustainable and cohesive neighbourhoods which will withstand these disasters need interventions by municipalities and state agencies to find appropriate policy lenses and relevant strategies with which to mitigate sinkhole hazards and minimise their impacts.

1.6 Objectives of the study

The main objective of this research report is to critically explore and define the interplay between community practice, development and dolomite related geotechnical conditions at Slovo Park informal settlement. The secondary objectives are therefore formulated from the research equations: 1) to investigate and define the critical social, cultural and household practices that exacerbate the level of risk on such ground; 2) assess awareness which exists among residents and the leadership with regard to human activities that could trigger the development of sinkholes using Slovo Park informal settlement as a case; 3) evaluate how the community is engaging with wet services such as water and sanitation facilities; and 4) finally develop recommendations on the subject of possible risk mitigation for the purpose of forming a support system for effectively managing and reducing the impacts of potential hazards in Slovo Park.

1.7 Main research question and sub-questions

The study will help present a clear overview of issues associated with dolomite related risks, and specifically the Slovo Park community's perspective towards the existence of dolomite on the settlement ground.

The key research question is: What is the interplay between developments, community practice and dolomite related geotechnical conditions at Slovo Park informal settlement?

In order to answer the main question, several sub-questions need to be answered:

A) What are the geotechnical conditions at Slovo Park informal settlement?
B) What are the social, cultural and household practices that exacerbate the level of risk on the dolomitic ground at Slovo Park informal settlement?

C) What awareness exists among residents and leadership on how sinkholes are activated?
D) What is the status quo of waterborne infrastructure in Slovo Park informal settlement?
E) How is the community in Slovo Park engaging with waterborne infrastructure?
F) What bearing do community-based practices, geotechnical conditions and developments have on one another?

1.8 Structure of the thesis

The study is reported in 6 chapters of a research report, consisting of the following:

Chapter One includes the background of the study, a concise overview of the problem statement, the sub-problems, the hypotheses, the assumptions made, the aim and objectives of the study, as well as the importance of the research, and the definitions of terms.

Chapter Two outlines a review serving as a vehicle with which the hypothesis is tested. This chapter draws on literature to determine the influence of social, cultural and household human behavioural considerations on inducing and activating anthropogenic dolomite hazards. It further looks at the inherent negative impacts of human settlements on environmental and geotechnical conditions, including a brief discussion of the debates in South Africa around development on dolomitic substrata. Through highlighting the exceptional examples of dangerous socio-cultural and household practices, it is possible to demonstrate the roles which education training programmes, including dolomite risk management plans, and other similar programmes may play as catalysts in minimising potential geotechnical hazards by informal communities.

Chapter Three goes on to present the geographic and policy background of the study area that came to be a conceptual framework. The chapter's first section draws on the contextual arena of the case study site to consider the stakes and stakeholders involved in the upgrading of informal settlements within the CoJ Metropolitan Municipality. Therefore, it contextualises Slovo Park informal settlement within Johannesburg and Southern Johannesburg and its close surroundings. Further, it also contextualises Slovo Park informal settlement in relation to the occurrence of dolomite in the province and, in more detail, in the closer region. These contextual descriptions become the basis of the fieldwork data presented in the last two chapters.

Chapter Four: Having established the key concepts, philosophies and factors which contribute to controversial debates on the upgrading of informal settlements sitting on dolomite, and the impacts of the associated human-led geotechnical hazards, this chapter proposes a methodology that is applied in the process of investigating what activities by the community may exacerbate the manifestation of geotechnical hazards. In this chapter issues relating to the data collection method, qualitative research process, and the validity and reliability of the research is discussed. This chapter also provides an overview of the social capital theory's theoretical framework as a tool with which to encourage awareness and mitigate risks.

Chapter Five presents the findings from the empirical research based on the study's objectives. The chapter goes on to discuss the results in terms of the key factors established in the third chapter. Significant reflections follow, drawn from the problems and perceptions of areas of success encountered. Given such critical reflections, it then can be determined whether the application of education as an instrument for increasing awareness of dolomite hazard formation, will yield the desired results.

Chapter Six: Having discussed and analysed the findings of the study, this chapter suggests recommendations aimed at creating awareness among community residents and the leadership. This chapter also provides conclusion to the research.

CHAPTER TWO
HUMAN SETTLEMENTS' IMPACT ON GEOTECHNICAL CONDITIONS

2.1 Introduction

This chapter reviews the theory and literature to assist in setting up the conceptual framework for the study. This process involves evaluating whether similar research studies have been conducted in the past as well as identifying applicable and appropriate methodologies and literature. This review discusses the anthropogenic hydro-chemical effects causing geotechnical hazards, which are normally overlooked in the very broadly applied South African dolomite risk assessment approach.

The review encompasses *investigating* and *defining* possible human behavioural practices that may have an effect on triggering sinkhole formation. Understanding the causes that lead to the activation and sudden manifestation of sinkholes in informal neighbourhoods is imperative, since more attention has been and is paid to the formal habitations, on which much have been written. This review focuses attention on the management of waterborne infrastructure, and social and cultural practices in the community that may lead to activating sinkholes and ground subsidence. This discussion may shed some light on the role that a community can play in evading such risk within its surroundings. The review shifts its focus to an understanding of risk management of sinkholes by proper management of wet services. Further to this, the discussion evaluates the role of urban and residential developments in altering the ground stability on slopes that lead to the formation of sinkholes. Finally, this review draws insights from the existing literature on the appraisal of the applied design techniques, material and servicing of waterborne infrastructure in residential spaces.

In order to address the theoretical discussion on anthropogenic hazards in informal settings appropriately, the terms 'social' and 'culture' are elucidated with regard to human actions as entrenched in the research's sub-question, of which social, cultural and household practices exacerbate the level of risk on the dolomitic ground at Slovo Park informal settlement. This is done to better serve the research inquiry. While these two concepts are often linked, in literature their meanings often are vague. Since I applied the two concepts throughout the research in relation to human actions and the social capital theory, and given their extensive influence in the built environment discourse, it is imperative to explain how they influence the ideas in this research.

Therefore, I explored both Rapport's (1990) and AlSayyad's (1993) examination of 'social' and 'culture' as concepts. It is worth noting that even from diverging standpoints, in the end Rapport (1990) and AlSayyad (1993) came to a consensus. From an anthropological position, Rapport (1990) proposes two approaches of splitting up the concept of culture for the purpose of gaining practical use for it in the urban architecture. First, he mentions that culture is a broad field, and that architecture is but a small fragment of it. Furthermore, the concept of social is a sub-category of culture in that social bears upon tangible things; to the real social behaviours, relationships, networks, structures and groups which are the actual materialisation of culture (AlSayyad, 1993). As such, culture bears on ideational things portraying the blueprint for social variables.

2.2 Sinkhole prevalence illustrated with case histories from South Africa

Historically, knowledge of the formation of dolomite sinkholes has been pivotal for planning. It involves determining the suitability of a site, and its geotechnical dolomitic category (GDC) for development and the construction of, among others, residential, commercial and transportation infrastructure on dolomitic terrains in South Africa. Theoretical and empirical studies on sinkhole occurrences emerged from a necessity of understanding such occurrences in order to inform public laws and regulations in South Africa for providing measures of protection against the environment for its inhabitants. To that end, it is the responsibility of the South African government to protect such spatially vulnerable communities from the risk of damage of property, personal injuries and in rare cases, the loss of lives (Van Schalkwyk, 1998).

The development of sinkholes related to the dissolution of soluble bedrock in the sub-surface and subsidence of the surface soil cover accounts for considerable disasters in many regions globally (Waltham *et al*., 2005). Historically, sinkholes have left a heavy footprint in selected parts of South Africa. Buttrick *et al*. (2001), pioneers in establishing the original method for assessing risk on dolomitic lands in South Africa, point out that at that time an estimated 4 to 5 million residents lived and worked on dolomitic sites. In addition, various municipalities, departments and consultants recorded over 2 500 subsidence events and sinkholes in South Africa over the last five decades (Oosthuizen and Richardson, 2011). They revealed that, on average, around 98 per cent of devastating subsidence events took place in, but was not limited to the Far West Rand (FWR), East Rand and Centurion within Gauteng with property damage estimated to be in excess of R1billion (*ibid*.). Buttrick *et al*. (1993) and as already mentioned Oosthuizen and Richardson (2011), assert that

the prevalence of sinkhole activities in certain parts of South Africa has led to the loss of at least 38 lives over the last six decades. An interesting fact is that not all occurrences are documented or declared, particularly when they occur on private land (*ibid*.). Therefore, the presented statistics are often based on limited data. It is important to note that both these historic and recent incidences began to draw caution to the fact that existing and future structures, including residential, commercial and transportation infrastructure on dolomitic land are at fairly undetermined risk to damage from sinking land.

The processes forming sinkholes can be largely attributable to human-induced changes in the subsurface, as well as by inflows through leaking pipes and irrigation. Despite the fact that sinkholes occur suddenly with minimal or no prior warnings, they may develop due to gradual influences by irrigation, groundwater extractions and the construction of impermeable structures such as pavements and closely-spaced buildings and gutters that terminate close alongside buildings, which changes the way water naturally infiltrates the ground (Oosthuizen and Richardson, 2011).

Development of ground cavities, radiating cracks on residential grounds and in walls are sufficient evidence of imminent sinkhole formation (Buttrick and Van Schalkwyk, 1998). This reality, however, contrasts the perceptions of many, especially politicians and government officials, about the occurrence of sinkholes. As noted, the Gauteng MEC for local government and housing, Mr. Humphrey Mmemezi (Times LIVE, 2011), declared that: “The dolomitic situation is satanic” and "[Residents don't realise] it comes during the night, people can wake up and the section [of the township] is not there". His view is particularly important to this research as it will be aligned with the Slovo Park community’s awareness of signs of ground instability or potential subsidence. In the same vein, this view highlights the need to understand how sinkholes develop in the urban landscape, and the critical factors that contribute to the activation of instability on slopes, and the subsequent formation of ground cavities.

2.2.1 Sinkhole definition

A better understanding of the gap between geotechnical interventions as strongly recommended in guidelines regarding dolomite land management (Storie, 2016), and the potentially life threatening role perceived to be played by informal settlement communities for triggering sinkholes or

subsidence occurrences in the absence of formal municipal services, as largely overlooked in both public and academic discourses, prove imperative at this point.

In order to critically understand the sinkhole phenomenon and what leads to its formation, there is a need to first define sinkholes or dolines. The Cambridge English dictionary defines a sinkhole as "a large hole that suddenly appears in the ground when the surface of the ground is no longer supported" or "a hole in the ground, especially in an area of limestone [dolomite] rock, that has been formed naturally, for example by water that has worn away the rock". Similarly, the Meriam-Webster dictionary's definition of sinkhole is "a hollow in a limestone region that communicates with a cavern or passage". While sinkholes and dolines are inadvertently used interchangeably, they vary in terms of size and scale of severity. Sinkholes tend to depict a typical diameter of less than 50 meters, whereas dolines exhibit a bigger diameter of 50 to 300 metres (Buttrick and Van Schalkwyk, 1998). Sinkholes are potentially much more dangerous given that they manifest in seconds, however, dolines are less detrimental as they often develop gradually (*ibid*.).

Buttrick *et al*. (2011) define sinkholes as the most characteristic feature of karst topography. In simple terms, it is a landscape where the underlying rock consists of limestone or dolomite. The latter is prominent throughout this research as the main challenge of the case study. Iannace (2002) asserts that dolomites belong to the sedimentary rock group which are major and abundant rocks close to the surface of the earth. Furthermore, sedimentary rocks are classified by the mechanisms of their formation, such as residual, chemical, clastic and organic rocks (*ibid*.). Chemical sedimentary rocks are classified by their dominant chemical composition, particularly carbonates. Dolomite refers to a highly soluble calcium carbonate [$CaMg(CO_3)_2$] rock, forming through a combination of magnesium and calcium (Oosthuizen and Richardson, 2011).

2.2.2 Sinkhole formation mechanism

The concept of human-induced hazards has the potential to further engage with the development of sinkholes. Sinkholes are primarily deemed as naturally occurring geological phenomena. However, they have diverse mechanisms of action at their core. Under natural conditions they take several years to manifest, even up to hundreds of years. Comparatively, human-caused sinkholes are relatively more prevalent, and inclined to decrease the natural timeframe to just days or even hours as already mentioned (USGS, n.d.). Almost 98 per cent of the 2 500 sinkholes and subsidence

occurrences comprehensively documented in South Africa (Oosthuizen and Richardson, 2011:21) can be attributed to human factors (Table 1). Urbanisation is identified as a leading human factor for inducing sinkholes (*ibid*.). The proliferation of human settlements in previous decades resulted in a growing need to use dolomitic terrain for development, and utilising groundwater aquifers as water resources in irrigated agriculture and developments. Given their extreme impacts, such activities affect dolomitic lands by exacerbating sinkhole and subsidence hazards (Durand, 2007).

Table 2.1: Human factors that influence sinkhole formation. Source: Adapted by Author from Durand (2007:76).

Land Topography	Human Factors
Overburden	Agriculture
Dolomite Bedrock	Land and water use Urbanisation Water pumping Construction

As pointed out in the previous discussions, sinkholes occur in places where the underlying rock is dolomite, a rock that naturally dissolves due to concentrated water ingress or even circulating ground water (Buttrick *et al*., 2011). Buttrick *et al*. (2011) further indicate that the common driving factor is acidic water, which essentially accelerates the dissolution processes forming underground cavities (*ibid*.). With this in mind, Oosthuizen and Richardson (2011) point out that sinkholes are dramatic in that the land surface it form on remain stable as they gradually develop until there is not enough support for the weight of the blanketing layer or overburden. Therefore, it results in a sudden subsiding of the land surface and the appearance of a sinkhole.

Some researchers such as Sartain *et al*. (2011) argue that it is impractical to predict the size and occurrence of sinkholes, given the varying geological and hydrochemical (magnitude of dissolution) factors contributing to sinkholes. Due to this unpredictability, hazard zoning on dolomitic land is challenging. Despite this challenge there is increasing pressure to utilise these dolomitic lands for industrial and residential developments, predominantly for the previously deprived black communities. In an attempt to address this challenge, researchers and geohazard practitioners

produce hazard maps through classifying empirical data correlating to the lithology of sinking dolomite. This technique of dolomite hazard mapping categorises zones underlain by dolomite bedrock into fundamental hazard categories established from the analysed empirical findings. Over the past two decades, this method has been the most common advancement tool towards development on dolomitic lands in South Africa.

2.2.3 Commonly applied approaches for determining sinkholes

Authors have suggested two methods to determine sinkhole formation (Buttrick *et al*., 1995; Hyland *et al*., 2006), which are applicable to this study. First, according to Buttrick *et al*. (1995), groundwater level and chemistry determine when the dissolution reaction will occur. During this process the saturated dolomitic rock react with acidic groundwater resulting in the rock dissolving into the groundwater. The dissolved materials of the rock leaves behind void spaces in the parent rock and subsequently cannot support overburden weight, resulting in sinkhole formation.

The second method emphasises the role played by human activities in forming sinkholes. In this instance, humans contaminate groundwater making it susceptible to slow weathering and the erosion of dolomitic rock underground over a long period. This results in the gradual decrease of the dolomitic rock's stability to support overburden material, and in this similar fashion sinkholes form (Hyland *et al*., 2006). The main driving force is the contaminated ground water or direct contact of percolating polluted surface water reacting with the dolomite rock. This process can be very slow or rapid depending on the scale of human activity polluting the ground water (Durand, 2007). Activities forming sinkholes in this fashion include leaking pipelines, septic tanks, broken sewage and over pumping and extraction of groundwater. This happens at a very slow rate. Dangerous practices include disposing chemically active domestic water from cleaning detergents; body scrubbing outside in the morning using water taps and soap with infiltration thereof into the soil on a daily basis. The application of agrochemicals in gardening and increasing soil erosion through ploughing and irrigated agriculture further tend to shorten the dissolution period. Placing this notion in the context of informal settlements, will reinforce understanding of how socio-cultural and household practices are hypothesised to exacerbate anthropogenic sinkholes. This view will become particularly relevant in the subsequent sections where this research discusses understanding the state of urban informal settlements, and their impact on the physical environment.

2.2.4 Sinkholes in South Africa

Geologically speaking, it would be remiss to have a discussion about sinkholes without identifying their types, and how they are formed differently. In South Africa, particularly in the Gauteng Province, the commonly documented sinkholes developed on dolomite grounds, and are characterised by cover-collapse (Oosthuizen and Richardson, 2011; Geocaching, 2014). Geocaching (2014) found that this type of sinkhole is more common in areas where the blanketing layer of the surface is predominately clay. As such, this layer is more solid and most likely to remain stable while cavities develop below the land surface. At this point, the bedrock gradually and progressively thins to form cavities up to the point where the underlying rock fails to support the blanketing layer, resulting in a sudden collapse (*ibid*.). This type of sinkhole is often anthropogenic and correlated to land-use practices and water ingress, for example, urban development, and the abstraction of groundwater.

Oosthuizen and Richardson (2011) distinguish this type of localised subsidence into two categories based on the formation mechanism. These are the surface dewatering-type and surface saturation-type subsidence (*ibid*.). They point out that a dewatering type subsidence, such as a doline, develops gradually and usually occurs as a large enclosed depression as opposed to a surface saturation type subsidence which manifests instantly, and can be relatively small at a size of about five metres or less in diameter (*ibid*.). The reason for this are 1) during dewatering type subsidence, deeply weathered rock such as dolomite produces unconsolidated debris from weathered material. When the ground level drops below a weathered zone, the soft, unconsolidated material cannot support the overlying load. The ground then starts sinking as a result of empty spaces in the rock; 2) Surface saturation type subsidence simply forms when water soaked ground sinks as a result of the overlying load from the surface. In this case, water saturates the ground as a result of artificial recharge such as pipeline leakage. The wet ground becomes soft and bedrock is less dense. This combination cannot withstand the compression of the heavy surface, and therefore the ground starts sinking down in that area. In short summary, for this subsidence type to occur there must be a shallow, soft bedrock and ground saturation from pipe leakage in a confined area. As part of this discussion, it is not the aim of this research to deem these two examples as the only sinkholes-forming mechanisms in South Africa, but rather to help in understanding the probability of sinkhole development under the influence of water ingress.

2.3 Sustainable human settlements on dolomite

This section draws on the discussion of sinkhole formation in *Section 2.1* to describe its impact on human settlements with an in-depth focus on informal urban settings. Human settlements present some of the most challenging and dynamic issues on the surrounding environment. Research shows that throughout time there has been an inherent and close interrelationship between humans and their environment (Berkes *et al*., 2008). Despite several studies which have been done on human-nature interactions (Turner, 1990), the complexity of human-nature systems has not been well comprehended (Berkes *et al*., 2008). This challenge is largely due to the convention of perceiving social and ecological sciences as unrelated disciplines. In order to understand the impacts of human settlements on geotechnical conditions such as dolomite, I find it appropriate to first provide a definition for human settlements.

Returning to the global stage, in his iconic work *Ekistics* (the science of human settlement), Doxiadis (1970) defines human settlements as human formed territorial arrangements. Perhaps even more relevant was the new definition drawn from this proposition by other authors through emphasising that human settlements are spatial arrangements erected by people within specific scales for supporting life (Brown *et al*., 1988). This definition is important to this research in that it considers the understanding that human settlements are in mutual interaction with the environment, within the constraints of which they have to operate and in which landscapes they exist on. Similarly, the United Nations Vancouver Declaration on Human settlements (UNCHS (Habitat), 1976), launched a statement in support of their definition of human settlements. The statement recognises that human settlements comprise of many variables that previously had been dichotomized from each other, such as building, housing, planning, as well as their relationship with the changing environment. This led to the current globally accepted definition by the United Nations (1997) which explains that from an anthropological stance, human settlements may be cities, towns or villages with all the cultural, material [environmental], social and organisational elements that sustain them. This evolved into the UN-HABITAT's (2007) vision of promoting socially and environmentally sustainable settlements development.

In this day and age of global influence from international development agencies such as the UN-HABITAT, among others, it is virtually impossible to overlook the impact of their decision on local planning and developments. As one of its mandates to act on this agenda, the South African

Department of Housing (1997:4) declared its aim to "establish and maintain sustainable, stable and habitable residential environments" in order to guarantee sustainable communities and households. This was undoubtedly guided by the view that interactions between environments and human settlements are complex and that they both pose direct impact on each other's sustainability (Berkes *et al*., 2008). In an increasingly urbanised world, it is very important to recognise the acute need for sustainable human settlements. This emanates from the fact that according to UN-HABITAT (2006:6), it is estimated that the urban population globally will average twice the rate of the 2017 global population by 2030. Furthermore, this takes into consideration that international trends reveal that Africa and Asia will experience the greatest proportion of urban growth (*ibid*.).

According to UN-HABITAT (2006), it is projected that by 2030 developing cities will host approximately 80 per cent of the global urban population with small cities, comprising of populations of less than 500 000 people and medium-sized cities with populations of one to five million people, constituting much of this urban increase. It is estimated that about 32 per cent of the global urban population resides in informal settlements and 90 per cent of these settlements are situated in developing cities (UN-Habitat, 2006). For instance, roughly 72 per cent of the urban population in Sub-Saharan Africa resides in informal settlements (*ibid*.:12). In South Africa, 58 per cent of the overall South African population reside in urban areas (SA, 2005:1). These statistics demonstrate the imperative need for resilient and sustainable human settlements in order to prepare for, prevent and manage possible environmental hazards that may result from the increase in population in the Sub-Saharan Africa region.

At this point, it is important to draw on insights on what is meant by sustainable human settlements. The *Breaking New Ground* (BNG) policy (SA, 2004:1) provides the widely accepted definition of sustainable human settlements:

> "well-managed entities in which economic growth and social development are in balance with the carrying capacity of the natural systems on which they depend for their existence and result in sustainable development, wealth creation, poverty alleviation and equity".

A human settlement largely considers the community residing in a certain area (Monto *et al*., 2005). It involves the surrounding natural setting that is transformed to accommodate and suit the community's demands on the environment. Worldwide, these communities are responsible for challenges that threaten the sustainability of human settlements (*ibid.*:50). This definition will assist

us in understanding the serious impacts of socio-cultural and household practices on dolomite in Slovo Park.

2.3.1 Understanding the state of urban informal settlements and their impact on the physical environment in South Africa

In this section, the reader will register a shift in the tone of the Chapter. This emanates from popular media, and anecdotal and empirical evidence incorporated into the literature in an effort to form a layered, complex picture of South Africa's urban informal settlements, and the environmental conditions they interact with. This sets a context in which the study is positioned.

A casual look at urban informal settlements in South Africa is more likely to produce such assumptions because through their home making processes and survival strategies the settlements tend to be chaotic, resource exploitative, and are constantly causing severe environmental impacts. This view reinforces the uninformed position of untrained passers-by who view their inherent character as being unsustainable, inequitable, inefficient, and wasteful settlements (DHS, 2009; Financial and Fiscal Commission, 2011). To delve deeper into urban informal settlements and their interaction with the physical environment, will provide an understanding that they are somewhat inefficiently informed on how best to manage their community-based practices in order to avoid degrading and altering the natural state of the land. These settlements are often situated in environmentally compromised or least desirable sites such as dolomitic lands (Huchzermeyer, 2009). Issues such as settlement, social and physical expansion, and big backlogs in basic service delivery present informal communities with challenges. Among others, they have to provide their own wet services in the absence of state-led interventions (Tissington, 2011). While these communities may be expected to wait for the city to install more taps for water provision, they informally install their own or illicitly draw water from existing communal water taps (*ibid*.:58). This practice can be dangerous on dolomite; it is often set up in the absence of proficient workmanship for installing these facilities. The informally connected taps are prone to bursting and leaking underground, thereby causing concentrated water ingress. This phenomenon has been a trend throughout South Africa's history of both township and informal settlement development. Households in such neighbourhoods lack sewerage facilities and refuse disposal services whereby refuse is removed by local authorities on a weekly basis. Consequently, they dispose of waste water and solid waste, including household chemical substances, in the environment in dug pits, already developed ground

cavities or existing sinkholes (Durand, 2007). The extent to which these practises increase negative impacts on the environment, remain to be seen.

Often, households with pit latrines use these toilets as wastewater dumping sites, leading to further concentrated ingress of water (Durand, 2007). Residents perform the washing of laundry sometimes daily at tap water spots in the streets, or within their yards. Waste water is frequently disposed of at these same sites. This again causes concentrated ingress (*ibid*.). These dangerous practices are inherently linked with the failure (from a human settlement planning perspective) to inform and educate the relevant stakeholders on water and waste handling processes, and to simultaneously address preconceived ideas. Given these reflections, the research considers the footprint of these environmental impacts.

In South Africa, informal settlements host approximately eleven per cent of the overall population (Housing Development Agency, 2013:15). While informal settlements cover less than two per cent of the overall surface area of South Africa, disturbingly, they exhibit a big environmental impact (*ibid*.). The environmental impact of particular concern to this research is associated with dolomite, and this impact has taken various forms over the years. Returning to the context of Gauteng Province, it can be further recognised that of the many formal and informal settlements situated here, about 110 sit on such grounds (Times LIVE, 2011).

Although dolomite is recognised as a universal phenomenon, interestingly, the Council for Geoscience (2009) points out that South Africa seems to be ahead of its global counterparts in terms of the management of development on dolomitic lands. Although this claim can be validated with the extensive empirical findings and technical investigations done on commercial, transportation and suburban residential developments, pro-active risk management of developments on dolomite is very rarely encountered in informal settlements. Similarly, the efforts to manage the risk of development on these geologically unsafe sites often fail to consider the anthropogenic impacts of informal settlements on dolomitic terrains.

Despite the aforementioned statistics of the affected informal settlements, only a few studies have been done to evaluate the dynamics of domestic triggering factors of sinkhole occurrence. In addition to substantial property damage and the disruption of communities by geotechnical conditions, human settlements unfortunately also contribute to altering the natural state of the land (Berkes *et al*., 2008). This parallels (former) Council for Geoscience Engineering Geologist Heath's

statement cited in Times LIVE (2011) that sinkholes are commonly anthropogenic and manifest in the presence of wet services due to communities migrating into areas where these facilities are available. He then goes on to locate its socio-environmental relevance through stating that in informal settlements, sinkholes are triggered by leaking taps or burst pipes (*ibid*.).

Although natural disasters tend to be inevitable in risk-prone locations where there is extreme urbanisation, as well as a lack of awareness or knowledge of existing risks, human-led disasters can be averted through proper planning, strategies and actions to mitigate risk and minimise vulnerability, as outlined in the Disaster Management Act (57) of 2002 and South African National Standards-1936 (2012). This research attempts to articulate the significance of educating informal communities to enable them to manage their community-based practises that may impact negatively on dolomitic environments. Such a process should be undertaken in order to achieve sustainable human settlements through reinforcing a programme of continual education to achieve pro-active practices.

2.3.2 Global Considerations

The global population has risen exponentially over the past two centuries, extending to seven billion people in 2011 (Biello, 2011). This staggering increase in human population saw rapid urban expansion and further demand for land occupation and an increase in anthropogenic impacts on the earth's natural system, for example, land degradation, activating of geo-hazards and high carbon-footprints (Hibbs and Sharp, 2012). It is important to note that humans are gradually learning how to deal with the challenges posed to the environment. This progressive learning is done through trying to attain a sustainable balance between the consumption of natural assets, and the need for preserving bio-resources (*ibid*.).

Moreover, humans are also learning to live in an altering environment by trying to understand the response of the environment to natural and anthropogenic changes such as climate change, residential developments and landslides. This advancement is coupled with the need to build settlements that are resilient to environmental disasters (Klein *et al*., 2003). Generally, certain areas across the earth are inherently more vulnerable to potential environmental catastrophes than others. This variance in vulnerability is essentially influenced by a number of factors, for example, hydrogeology, geomorphology and the geology of the surrounding environment (Doctor and Doctor, 2012). In the case of dolomite, the two prominent factors are hydrology and surface morphology,

which relate to subsurface and surface geological conditions respectively. The resource demand growth leads to continuous occupation of fragile and sensitive dolomitic terrains. As mentioned earlier, informal communities are learning to live and interact with the dolomitic environment in order to mitigate hazards from happening on these vulnerable lands. Therefore, this part of the section deals with the situation of South African human settlements, and their impact on the physical environment.

2.3.3 South African Conditions

The stark reality associated with the staggering increase in the urban population in South Africa, recognises that while urban areas may offer many advantages that can promote sustainability, such as basic service delivery, urban sprawl is associated with alteration of the natural system, particularly on the slopes of the land. The rapid influx of people into already overcrowded urban areas with significant service delivery backlogs has resulted in the manifestation of informal settlements in vulnerable locations like dolomitic areas, among others, including Slovo Park. While this research is focused only on Slovo Park, it is worth indicating that almost half of all informal settlements in South Africa are categorised as being most vulnerable to environmental issues (Buttrick *et al*., 2011).

Often, the reluctance to provide basic services delivery in some of these vulnerable locations is strongly linked to the nature of the surrounding environment (Berkes *et al*., 2008). Hazards linked to dolomitic lands are rapidly increasing, and as developments expand and the demand for wet services increase it is often met with lack of adequate planning that fail to consider the peculiarities of these environments (Durand, 2007). In most cases, these challenges have resulted in an increase in dolomite related environmental and engineering problems such as sinkholes (*ibid*.).Despite the increase in technical and scientific knowledge on sinkhole related issues, coupled with the capacity to mitigate and manage incidences of sinkholes, the overall subsidence damage can be expected to increase in future, for numerous reasons (Gutiérrez, 2010). Key to these reasons is urbanisation 1) residential structures on sinkhole prone locations will keep on increasing 2) the impact of human activities that contribute to sinkhole development will be relatively higher 3) today, relatively little or no information is being shared among communities living on dolomite on how to prevent and manage sinkholes.

2.3.4 The status quo of lack of awareness of potential risks

Even with the confirmed existence of dolomite in Slovo Park, no sinkhole has yet been found in this area. This has led to another misconception so that for many this seems to be a reason enough to believe that they are not under any threat from sinkholes materialising on their doorstep. As pointed out in Times LIVE (2011): "They believe dolomite is being used as an excuse for removing informal settlements". In contrast, underground cavities and other potential subsidence structures may go unnoticed, even with the use of expensive geotechnical apparatus (Gutiérrez, 2010). Often local experts, including structural engineers and geologists, conduct several geotechnical investigations prior to developments. However, far too often such expert investigations tend to decrease dramatically or cease entirely once a sinkhole-prone location has been developed. Although sinkholes seem impossible to detect *via* mapping tools, through education relevant stakeholders can help to minimise the risk of activating potential hazards.

2.4 Conclusion

The aims of this chapter were to define the geotechnical conditions inherent in South Africa and around the area of study, and possible human activities that tend to cause sinkholes or subsidence occurrences, paying special attention to socio-cultural and household practices. This chapter evaluated the prevalence of these conditions and their historical impacts on infrastructure and humans with particular reference to Gauteng Province. Furthermore, it described how a geotechnical condition, namely dolomite, is perceived by informal communities in South Africa.
The hazards resulting from these geotechnical conditions were also defined, providing various mechanisms responsible for triggering hazards, and suggestions were made of how to determine the development of these hazards.

Key issues were identified from the sustainable human settlement approach as applied locally and internationally, maintaining that informal settlements are not only to be seen as resource exploitative, and the constant cause of critical environmental problems but rather as spatial arrangements where well managed available resources, combined with community-led interventions, can be utilised to improve livelihoods. The discourse examined in this chapter validates that with massive service delivery backlogs, informal settlements are required to provide or expand their own wet services for everyone's benefit and convenience. As in most cases, this is

done in the absence of proper workmanship for the installation of these services. The incorrectly installed services are prone to leaking and bursting, causing ingress of water and thus leading to the manifestation of geotechnical related hazards. These occurrences are often exacerbated by erroneous domestic use of land and water in various activities highlighted in the foregoing sections.

Chapter Three will accordingly provide more background of the geotechnical conditions inherent in the area of study, and their impacts on the community along with the state of the community's preparedness for dealing with or mitigating the accompanying hazards of these conditions.

CHAPTER THREE

GEOTECHNICAL CONDITIONS WITHIN THE URBAN CONTEXT: THE CASE OF SLOVO PARK INFORMAL SETTLEMENT

3.1 Introduction

This chapter extends beyond simply presenting the background for the fieldwork phase. It reflects on the critical implications of informal settlements' interactions with dolomite hazard prone environments in the current urban discourse and practices in the CoJ. It draws from local scholarly debates and previous discussions in this report to examine the CoJ's sustained reluctance to implement *in situ* upgrading in communities affected by environmental and geotechnical conditions. The tone of the City's response to the upgrading of these informal communities suggests that it is dealing with insignificant, criminal, and disturbing processes. The highly publicised and imminent sinkhole events in some of these areas arrested the attention of the City's officials (Times LIVE, 2011). However, the will to mitigate these forecasted challenges without the use of the controversial and community fragmenting concept of 'relocation', does not exist. This section will consider the City's steadfast strategy for 'relocation', and show how this strategy is frequently used as a convenient and compromising tool to not redevelop, regardless of the needs/interests of the informal occupiers of land.

This chapter further goes on to present the geographic and policy background of the study area, which culminated in a contextual framework. Its first section draws on the contextual arena of the case study site in order to consider the stakes and stakeholders involved in the upgrading of informal settlements within the CoJ. It therefore contextualises Slovo Park informal settlement within Johannesburg and Southern Johannesburg, and closer surroundings thereof. Further, it also contextualises Slovo Park informal settlement in relation to the occurrence of dolomite in the province and, in more detail, in the closer region. These contextual descriptions become the basis of the fieldwork data presented in the last two chapters.

The intention with this report is to provoke a shift in planning and strategic approach by the CoJ for developing areas prone to sinkhole activities. The intention also is to place strong emphasis on educating the residents of these settlements on how to deal with such environments and the associated hazards. At the same time, the aim is to encourage the CoJ to set up a proactive DRMP, rather than resorting to relocating residents.

The chapter scales down to the localised description of the socio-environmental context in which the case study site is located. It introduces the relevant stakeholders involved in the upgrading of the area, namely the community, CoJ and dolomite risk management practitioners. It presents the case of Slovo Park informal settlement, which has a prolonged and complex history with the City around the issue of *in situ* upgrading on dolomite. The community has documented this well over the years, and the chapter also deals with how these issues inform the views on the current developments in this area.

This Chapter further looks at how the city's struggles with housing have influenced non-state community-led interventions in informal settlements. While perhaps well-intentioned by informal residents, the diverse socio-environmental activities required for sustenance, prosperity and security have harshly impacted not only on development, but to a greater extent on the vulnerability of settlements residing on dolomite. The chapter also reviews the UISP, the City's disaster mitigation framework, and the law which obliges the City to have a certain level of preparedness for disaster risks it is aware of. The important theme throughout is the interrelationship between community-based practices, dolomite and residential developments within the CoJ. The Chapter concludes with a review of applicable dolomite regulations and legislative actions needed to minimise those human activities that may exacerbate dolomitic hazards. This can assist in preparing these communities for future occurrences, and to better protect them.

3.2 The Investigation Site

This section provides details and background information relating to the study site. Slovo Park is an informal settlement located approximately 10km south of Soweto (Figure 1.1). The informal settlement sits within the CoJ Metropolitan Municipality in Gauteng Province of South Africa. The area is situated adjacent to the southern Nancefield Industrial area, a wide floodplain of the Klip River, and is bordered by N12 Moroka Bypass to the north (Figure 1.1). The residential *erven* cumulatively measure roughly 46 hectares (not officially surveyed) in extent, which could accommodate about 1469 of the total 3734 households residing on 300m^2 plots in Slovo Park (CoJ, 2017).

The exact extent of the portions of land suitable for residential use, was investigated in terms of environmental and geotechnical suitability (CoJ, 2017). Topographically, the land is very flat and gently slopes towards the streams on the eastern portion of the land. All geotechnical studies done

historically, up to the most recent conducted in April 2017, indicate the existence of dolomite in Slovo Park (Appendix I). The set developments will consider restricted foundation recommendations and water bearing infrastructure designs for the affected residential stands (CoJ, 2017). Compounding this has been the infill drilling findings (Appendix I), undertaken to adhere to the SANS-1936 (2012) Act. The findings' outline is: 44 of the 46 hectares of *erven* are classified as Dolomite Hazard Zone 1 (D1). This part of the land portion is determined to be 1-2 (medium) '*Inherent Risk Classes'* in relation to water ingress. The approximately two hectares that remain are classified as Dolomite Hazard Zone 2 (D2). This land section exhibits 2-5 (medium to high) '*Inherent Risk Classes'* characteristics in relation to water ingress (Council for Geoscience, 2017).

Geological and Environmental background of Slovo Park informal settlement

The underlying bedrock geology has been established with reference to Figure 3.1, which follows the Intraconsult report, IR1401R, dated April 2017 (Appendix I).

The entire site is underlain by dolomite and weathered soil derivatives of the Chuniespoort Group, Transvaal Supergroup (Oosthuizen and Richardson, 2011). It is likely that the area is underlain by the Oaktree and Monte Christo Formations of the Chuniespoort Group. The Formations are "important examples of a primitive dolomite, exposed to deep burial, tectonisation, and folding, uplifting, and longstanding events of erosions of rock fragments within the Kaapvaal Craton" (Barnard, 2000). The Chuniespoort Group karstified dolomites is deemed to be one of the most significant aquifers in the Country, and is the only readily available water resource for numerous farms, rural areas and towns. Gauteng has a need of such water for the expansion of industrial and urban complexes (*ibid*.).

The dolomite and chert typically weather to chert residuum, dolomite residuum, including weathered altered dolomite (WAD), and various combinations of the two material types (*ibid*.). Thick deposits of colluviums typically blanket the residual dolomite in the central and western areas and alluvium in the eastern boundary area, thus making it difficult for residents in the area to see the dolomite. Therefore it makes them sceptical about the risk it poses. In addition, the site is located in the Klip River Groundwater Compartment, which is not subject to dewatering.

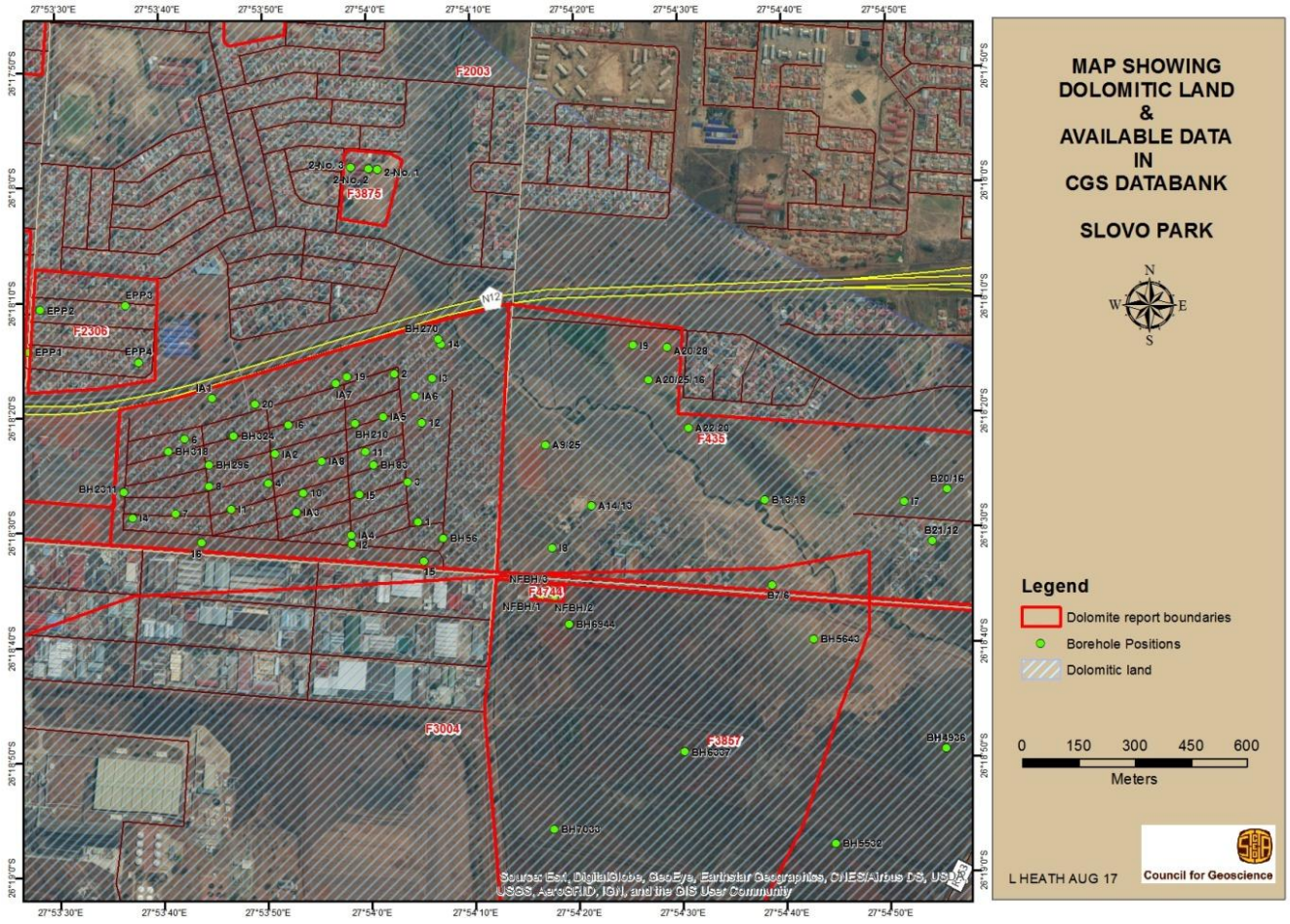

Figure 3.1. A Council for Geoscience (after Heath; 2017) unpublished Map of Slovo Park informal settlement depicting the land considered to be dolomitic.

Slovo Park informal settlement has been existence since 1990, and therefore the formalisation of this settlement will not have a negative effect on the surrounding land uses. Overall, the "site is not environmentally sensitive, except the north eastern corner where there is an interface with a wetland area" (CoJ, 2017:7).

3.3 A policy background of Slovo Park informal settlement

3.3.1 Project Background

Slovo Park is an informal area which sprung up in the final years of apartheid South Africa. This was brought about by need and an increasing trend under black people to reside close to employment areas.. The upgrading project falls under the jurisdiction of the CoJ Metropolitan Municipality (CoJ, 2017). During the fieldwork of the research, it was interesting for the study to observe the urban

farming reflected in the research findings. Figure 5.4 exhibits examples of the participants' yards with small-scale gardens comprising of ornamental and vegetative materials. In informal settlements or slums the significant barriers to urban farming are availability of space and ease of access to water (Maxwell, 1995). Slovo Park's density is relatively high and almost each yard has access to water from the stands' pipes. Other authors paid attention to this by documenting these phenomena. These investigations indicate how urban farming has become an aid in response to the staggering levels of unemployment and poverty in informal settlements. At the same time, those activities also shape the socio-environmental dynamics.

The field data collected during this study revealed that more than half of households (not officially surveyed) in Slovo Park have no formal jobs or even a source of income. The interviews explained that the residents of this settlement profoundly rely on informal means, among others, for subsistence. This includes renting out backyard rooms, growing small-scale crops, selling vegetables and scrap metal, and through micro-scale businesses such as "spaza" shops. A fraction of the residents are employees of the adjacent Nancefield factories.

Slovo Park, as one of the informal settlements in Region G of the CoJ, was then identified for *in situ* upgrading. In 2007, the Gauteng Department of Human Settlements commissioned the required studies to determine if the area can be developed or not. This was prior to the Slovo Park Community Development Forum (SPCDF) taking the City to court for the redevelopment of Slovo Park. The SPCDF took the CoJ to court of 5th April 2016, and the Court ruled that the City should submit an application for funding under the UISP to the Gauteng Department of Human Settlements. As per the Court order of April 2016, the City has appointed consultants through its Attorney's on Record on this matter to undertake various investigations that will assist it in preparing the application for funding under the UISP. Since the appointment of consultants in January 2017, three land parcels were identified as potential sites that would be utilised to de-densify Slovo Park, given that it is currently highly populated (CoJ, 2017). Given that the area is affected by dolomite, only certain land uses are allowed where specific foundation recommendations and wet services designs will apply. I conducted my fieldwork in Slovo Park informal settlement in August 2017. At that time, the upgrading project had not yet commenced.

3.3.2 Upgrading informal Settlements in South Africa

In South Africa, the current democratic government of the African National Congress (ANC) inherited several service delivery challenges from the colonial regime of the National Party (NP). At the heart of these challenges is the national housing backlog, which is most prominent in the townships and informal settlements. The apartheid government was not only successful in its systematic and long-standing deprivation of black people of access to land, but also of the provision of access to adequate housing with land ownership (Rugege, 2004). It was because of apartheid laws and policies that many black people were driven to the outskirts of the cities, which led them to resort to erecting informal settlements and occupy inhabitable lands. Disturbingly, the remnants of this remained even post-apartheid, as the majority of the black community still lives in informal settlements, and on sites that are both environmentally and geologically unsafe (Huchzermeyer, 2009).

Since the dawn of democracy, the current government has adopted numerous policies and implemented several laws in order to redress the basic service delivery deficit and housing backlog (Rugege, 2004). Among the efforts to break away from the shackles of the past, which were rooted in gross human rights violations and inequality, is the transformative vision, also, the undisputed obligation to provide access to dignified and adequate housing for everyone living under their localities of jurisdiction, as entrenched in the Constitution's section 26 (1) and (2) (Constitution of RSA, 1996). These obligations are bound by the policy and legislative framework outlined in the National Housing Act (107) (*The Housing Act*, 1997). Even with such efforts, the housing backlog still thrives. This is attributable to the unique housing problems facing the poor in this country, as well as a significant influx of migrants in cities (Rugege, 2004). These, among others, include issues related to the construction of houses and geological safe site selection for the building of houses (Huchzermeyer, 2009).

This section explores the CoJ's legacy of slow progress with *in situ* upgrading of some of the region's informal settlements, and upgrading choices that the City is now making with its current planning strategies (Huchzermeyer, 2009). The section also explores if the City has made a shift to modes of development that address housing challenges, while placing socio-environmental issues faced by informal settlements at the heart of these policies and strategies. The informal settlement of Slovo Park, located in Region G of the City (CoJ, 2017), has been in a prolonged conflict with the City for

upgrading, dating back to the early 2000s. This hurdle evolved into continuous shifts in policy and resulted in service delivery protests and a lawsuit against the City. As a result of lack of informed knowledge about the manifestations of sinkholes in dolomitic conditions, the SPCDF rebelled against the contemplated relocation of part/some of the residents to Unaville. The CoJ therefore became reluctant to proceed with developments in Slovo Park, leaving the community paralysed in a state of limbo. This challenge is frequently guided by the untrained observer's misconception that informal settlements constitute temporary housing. This, then, makes relocation policies much more palatable.

However, more often than not informal settlements tend to resemble a high level of informal reciprocal networks and social cohesion. They also have a longer duration of stay than outsiders may think (from a few years to decades). It follows that further understanding of these settlements and their "home making" processes should be central to the planning of redevelopments. Alarmingly, the CoJ argue that the relocation approach addresses the problem of long-term sustainability, environmental and geotechnical issues of a specific site. This emerged particularly when the municipalities, ironically, applauded their own determined attempts to realise the "Cities without Slums" tenet as entrenched in the Millennium Development Goal Target (11) (Huchzermeyer, 2011).

The little literature available on the subject shows that people living in informal settlements use social capital qualities to their advantage for generating better livelihoods. Affected communities' fear of losing livelihoods inspires the idea of standing in solidarity to resist fragmentation of these hard-earned social bonds *via* relocation. The respective communities form crisis committees and grassroots social movements, which often turn into development committees, to contest these earmarked relocations against the government (Tissington, 2012). Apart from social movements and protest, informal communities use the courts in their arsenal in their fight and to obtain *in situ* upgrading.

The motivation for protests is to pursue their constitutionally guaranteed socio-economic rights. As in a case of eviction, courts often consider the reasonableness inquiry on earmarked relocations in order to establish if the measures taken by the government are reasonable. The reasonable review is necessitated in twofold, when the court finds that the relocation of informal residents is unjust and inequitable. First, the consideration of the availability of suitable alternative land would depend on numerous factors, including how long the residents have remained on that land, and the number of households facing relocation, proximity to places of employment, serious consideration of the

residents' request for *in situ* upgrading, the issues related to something suitable for the informal residents without prejudicing the claims of these residents.

Second, the exact extent to which the residential portions of the available land is affected by environmental factors and geotechnical conditions. In the case of a site possibly underlain by dolomite, local experts undertake specialised studies to confirm the level of severity of this condition on developments. If the identified "Inherent Risk Class" of the area meets the NHBRC *Site Class* criteria for development (Heath, personal communication, 18 August 2017), what recommendations with regard to construction methods may be made to allow for *in situ* upgrading, considering that the site still holds critical geotechnical risks? In a sense, this shifts the focus from relocating informal residents to finding innovative ways of providing homes for all.

Returning to the context of Gauteng, Gauteng MEC of Human Settlements and Co-operative Governance and Traditional affairs, Mamabolo (Property24 News, 2014) suggested that "mixed housing plan will be ideal for areas affected by dolomite". This statement parallels Heath's (personal communication, 18 August 2017) suggestion that in high risk areas (between 3, 4 and 5 inherent risk classes), multi-storey and mixed-use developments are recommended. This harks back to Kirsten *et al*.'s (2009, 2014a, 2014b) proposed risk-based evaluation method of the influence of development density on personal safety. In contrast to Mamabolo's statement, Kirsten *et al*. (2014b) argue that a mixed-used development model isn't about mass densification, which in the case of dolomitic conditions is prohibited. In this context, they look at development density through the lens of sinkhole footprint (*ibid*.). When high risk conditions are encountered on a land portion, a suitable footprint is to be examined. To this end, the inspector should confirm that the housing unit and pedestrian areas closely around the housing structure are all located within a verified area and are sufficiently dealt with to avert the formation of sinkholes. Simultaneously, such development should allow for safe mass evacuation in the event of subsidence manifestation.

Kirsten *et al*. (2009) further asserts that no structures should be constructed on the remaining portion of land, including small structures, given the high risk of structures collapsing into sinkholes. This takes into consideration that the installation of water features or wet services on the remainder of the land may be equally damaging to "poor" Inherent Risk Classes areas. However, as Chapter Two has shown, informal communities often refute the claim that the areas' geotechnical conditions are not suitable for *in situ* upgrading. This is largely driven by the desire for conventional zoning practices

where each stand can only accommodate a single household, for instance, the preferred standard Reconstruction and Development Project (RDP) houses or yards. An interesting fact is that "conventional construction" in this context refers to building methods and procedures in which no particular precautions are taken to prevent sinkholes (Kirsten *et al*., 2014b), and no other options than raft foundations are considered. For example, steel rafts constructed above ground, as opposed to subsurface steel and concrete rafts, are not even considered. The idea of altering informal dwellers' own residential plans promotes misconceptions around the State's recommended residential plans among informal residents.

The informal residents' objection to the idea of constructing mixed-use developments and government subsidised communal housing blocks, affords municipalities with a solid reason to delay or not develop these areas as initially proposed. However, municipalities recognise that residential densification may stimulate economic prospects in informal areas, which can be to the government's advantage. Despite seeing no signs of development, informal residents often approach the Constitutional or High Courts to bring suit against municipalities while at the same time asking for rudimentary services in the form of water taps, toilets, sewerage and waste collection, and electricity. In cases where settlements are not yet formalised the provision of such interim services is essentially communalised, and thus may not be convenient or to the benefit of everyone.

As pointed out in the foregoing chapters, a closer look into some of these communities is likely to show the ingenuity with which residents largely find ways for serving their entire communities from the available resources. This often implies creating informal or illegal electrical and tap water connections to their respective stands. This approach certainly creates further vulnerability in these settlements as the illegal connections of water taps are prone to bursting and leaking, causing high concentrated water ingress and over extended periods. Based on the argument set out in Chapter Two, the three key threads throughout this research that deserve consideration are social, cultural and household practices, which have resulted in a problematic trend of informal settlements, which exacerbate sinkhole manifestation.

As seen in some of the informal settlements, including Slovo Park, these problems have been the major outcomes of illicit water connection. Illicit water connections are carried out in pursuit of convenient access to water from residents' designated stands or yards, rather than having young

men, children and women wait in line for long hours for water from a communal tap. This highlights the problematic nature of municipalities' to deliberately allow these communities to suffer continuous vulnerability, given that these areas are seldom treated to minimise the risk of subsidence. The underlying motivation for this lack of action can be argued from two perspectives. First, that government is eroding citizens' 'right to adequate housing' through the provision of unmonitored interim municipal services. The provision of inadequate basic needs often is not the objective of service delivery policies. However, it can become so when its practices are economically more viable in comparison to the associated costs of the delivery of bulk services', and the monitoring of their sustainable use. Despite government's efforts to provide the much needed infrastructure improvements, these minor improvements do not leave the informal resident feeling a part of the municipal fabric (Huchzermeyer, 2009).

The second is that there are things to be learnt from these settlements and their journeys to achieve developed community spaces. In their outcry to attain the desired social services, by means of street protest, informal communities, unsurprisingly, sometimes resort to destroying the existing insufficient infrastructure. This again raises the question: could this be another angle of addressing the government? Informal residents are not given enough by the government for them to continue to wait and accept (Rugege, 2004).

The persistent informal sharing of the available resources in informal settlements, leads to the criminalisation of informal communities. As Ntoahae (Personal communication, 27 July 2017), a prominent member of SPCDF Committee, shared about the invariably criminalising ideologies and actions that interface with the government's agendas:

> "We have learned from our experiences that when you try to use your own survival strategies to make your living spaces a better place while waiting for their [municipal government] long promised basic services [provisions] your livelihood endeavours becomes criminal".

This statement raises two questions. First, do the existing policies for providing interim basic services reinforce the continuous monitoring and reviewing of these services by municipal governments; and, second, to what extent have the current post-apartheid upgrading strategies or *in situ* upgrading policies given substantive content to the environmental safety of informal settlements? Drawing on

cases of death associated with illicit electric connections, these informal settlements still remain highly endangered zones in terms of sinkholes attributable to illicit water connections for local residents (South African National Standards, 2012). It becomes increasingly clear from literature that at present there is no single authority that bears complete control, and, therefore is completely accountable over what happens on dolomite. There are no available insurance coverage and umbrella funds to compensate those who suffer from sinkholes disasters (Kirsten *et al.*, 2009).

3.4 Socio-environmental status quo of Johannesburg's informal settlement, and Slovo Park in particular

This section looks at the unfulfilled socio-economic rights guaranteed by the Constitution, and that the urban poor are increasing being overlooked by municipal governments. The Constitution, along with various Ordinances and Acts, impose a duty on the relevant arms of government to guarantee the health and safety of people living within their areas of jurisdiction (Constitution of RSA, 1996). This, of course, takes into consideration the associated geological problems (*ibid*.). It can safely be said that dolomite associated issues, in particular, pose a greater challenge for the responsible authorities to address. In order to address issues related to potential environmental and geotechnical impacts of a site, the National Housing Code 3 (3) makes it mandatory for developers and municipal governments to undertake the relevant studies. These involve environmental and geotechnical surveys of the soils and ground stability prior to any infrastructure development, as set out in the NHBRC Soil Site Class guidelines (Heath *et al*., 2007).

When looking at the geotechnical aspect, the investigation includes establishing soil conditions, dolomite stability, bedrock depths, geo-hydrology, perched groundwater conditions, inherent risk classes and', if the identified locality is dolomitic, dolomite area designations assessment is necessary (*ibid*.). Look (2014), argues that this designations assessment requirement often is not adhered to. On numerous occasions, developers have been authorised to construct buildings without thorough environmental studies and geotechnical site investigation having been conducted (Kirsten *et al*., 2009).

In their review of *Approach to sites on dolomite*, Heath *et al*. (2007) comment on this negligence, stating that municipalities often will consent to proposals made by opportunistic developers whose intent is to maximise their revenue in developing projects on land segments that are under the

jurisdiction of the municipalities. Developers are liable for appointing and paying of the geotechnical specialists for land-risk examination (*ibid*.). The developers then approach the local authority to allow a higher order development density (*ibid*.). This allows developers to get a greater return on investments with reference to the properties. This infers that it does not matter to developers that the proposed land for development is not suitable for densification due to the associated geological issues, and that they should refrain from densifying or even building on it. Returning to the case of Slovo Park, for instance, the appointed developers should be cognisant of the severe susceptibility of D2 to subsidence and sinkhole activity. Consequently, this will impede any residential development, as opposed to D1, which is less prone to subsidence formation, and can allow for both low and high rise housing units (CoJ, 2017). It will, therefore, be a disappointment should such developments be erected on D2.

One could perhaps argue that this unprofessional practice is the cause of many houses experiencing structural damage and severe cracking due to ground instability and sinkholes activity within a few or several years of completion. Should any detrimental environmental issues or problem soils be encountered on the site, possible solutions to construction in those areas are normally articulated to the communities concerned. Slovo Park, D1 in particular, is "limited to Res 1 free standing houses to be on 300m² and Res 3 stands high density housing to have a density of 120 units per hectare" (CoJ, 2017:7). This could often rule out the hope for *in situ* upgrading of informal settlements should an area not meet the environmental and geotechnical criteria for development. Therefore, these particular communities are often forced to relocate from their current settlements to be resettled elsewhere in alternative areas identified by municipal governments as geologically safe for suitable development. This parallels what was pointed out earlier, namely that the remaining 2 265 households of the overall number of 3 734 in Slovo Park, are destined for relocation to Nancefield Township, Lehae Expansion Area and Lenasia Extension 10, for reasons of de-densification (*ibid*.).

It falls within the ambit of the Provincial Housing Department as well as that of the relevant arms of government to embark on a comprehensive social awareness programme that will address the aforementioned geotechnical problems. Failure to implement these programmes will hold serious financial implications for the municipalities as these communities will likely seek help from these very same municipalities. In addition, it is essential to implement a pro-active dolomite risk management plan (DRMP) in order to prevent or lessen dolomite-related incidents (SANS 1936-1, 2012) for particular risk categories. Through awareness programmes, relevant departments and role

players should be identified who will ensure that informal settlements are educated on what the causes of sinkhole activities are, and how to mitigate these problems. This is to be done to fulfil the people's constitutional right advocating for their protection, and to live in a safe environment. Look (2014) states that planners should have a guidance plan that will ensure the long term sustainability of the occupation of dolomite areas. Echoing this, Heath (personal communication, 18 August 2017) asserts that in recent years a DRMP has become a legal obligation, to be incorporated in the planning of developments on dolomite lands in accordance with the 2010 Geosciences Amendment Act (16) NHBRC guidelines (Act of 1977), and SANS 1936-1 (2012). The CoJ must recognise the extent to which a DRMP can contribute to community safety awareness during and post the upgrading of informal settlements.

3.5 Conclusion

In order to ensure that informal settlement residents' perceptions and attitude towards dolomitic environments within the CoJ Metropolitan Municipality are altered and that people participate in meaningful ways to conserve their environments, problems as were reflected this Chapter need to be addressed. As the managing of settlements on dolomite is not limited to geotechnical interventions, it is important that the CoJ recognises the role that human behavioural considerations could play in minimising the level of risks in these environments.

Key issues based on this Chapter:

1. Management of developments on dolomite is a highly politicised process in the context of informal settlements.
2. The Municipalities' failure to recognise the *de facto* socio-environmental interactions in informal settlements in order to adopt DRMP as an imperative and social awareness programmes to educate the communities concerned.
3. The lack of bulk or adequate wet services, and poor water management practices in informal settlements.

The subsequent Chapter presents the theoretical framework, research design and approach, and ethical considerations taken to address the study.

CHAPTER FOUR

THEORETICAL FRAMEWORK AND RESEARCH METHOD

4.1 Theoretical Framework

In order to develop an academic context for the research, I shalll identify a theoretical framework for guidance. Social capital theory will be used as the theoretical framework for the purpose of this study. According to Sakaran (2000), social capital theory is a conceptual model of the manner in which a researcher or investigator makes logical sense of the relationship between various factors that has been identified as significant to the problem. The selection of this model was prompted by the fact that it allows for the involvement of local people in defining and providing relevant solutions to the problem, where possible. Community awareness seeks to prepare residents for communal efforts in controlling and mitigating possible manifestation of geotechnical hazards. Nielsen and Lidstone (1998) point out that education is the development of skills and knowledge to empower people and encourage informed decision making.

Social capital theory is defined by Claridge (2004:38) as being concerned “about the value of social networks with the norms of reciprocity”, and is considered relevant to this study’s theoretical framework in that it is linked to public awareness It therefore describes the intensity and patterns of networks between people and the shared values that stem from such networks. The main aspects of social capital theory are identified in this order: 1. Reciprocity -community awareness will boost the mutual interaction and interdependency that occur in furthering the transfer of knowledge to other members of the community on how to control and mitigate geotechnical risks. 2. Networks - The significance of community awareness is that it ensures that information which is communicated within social groups will be precise and accurate with regard to geotechnical risks.

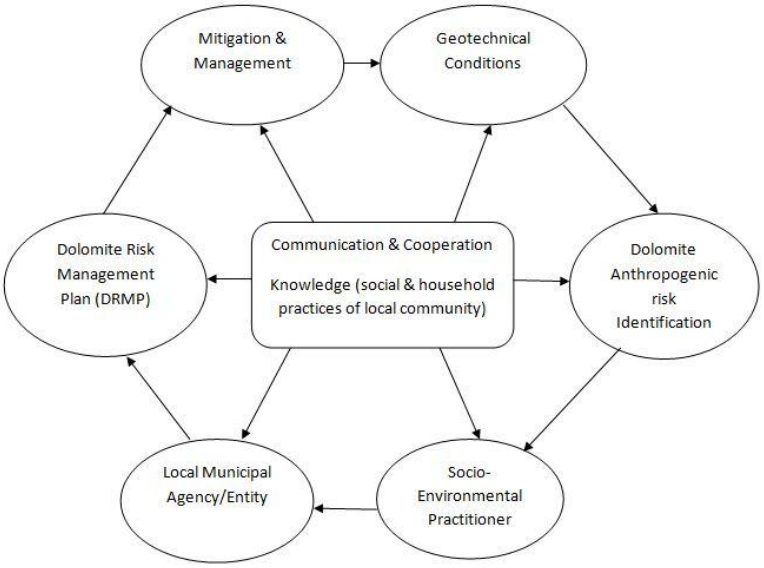

Figure 4.1. Conceptual Efficient Dolomite Risk Mitigation Framework. Source: Own Construction (2017)

Geotechnical condition refers to the presence of dolomite on existing land (Heath *et al*. (2007). Therefore, the identification of dolomite-anthropogenic risk involves assessing environmental risk factors associated with land and water use, existing developments, and social activities within the area of concern. The natural state of the land altered by the built environment and human activities, operates autonomously and usually the people have little control over these processes (Berkes *et al*., 2008). However, it is possible to understand and predict general processes and trends associated with the surrounding environment (*ibid*.). These processes demonstrate the relations among the community's living environment, lifestyles, activities, and the built form. These aspects need to be strongly considered in setting up a social awareness programme and a DRMP (Figure 4.1). Community stakeholders and the stakes are important in achieving sustainable and stable communities (Claridge, 2004). As shown in figure 4.1, mitigation and management of developments on dolomite does not only involve DRMP, but also take into consideration the social and household activities of a local community, which forms part of the dolomite risk factors. In essence, the figure above is used in recognition of the fact that in order to fully address geotechnical conditions and their associated risks, effective communication and cooperation among all important role players, including the local municipality, dolomite risk managers, socio-environmental practitioners and the community is essential. This is because human activities are inclined to exacerbate dolomitic hazards.

4.2 Introduction

This section draws on the study to the point that it recognises the critical concepts that are required to be woven into field study. In this sense, it goes on to communicate the 'hows' and 'whats' for the collection of data.

Researchers have diverse methods of and philosophies for observing and interacting within their environment (Wahyuni, 2012). Consequently, distinctive methods of research study emerge. However, there are set principles and standards or instructions and criteria that guide a researcher's actions and philosophies. These standards, principles and criteria are universally defined as a paradigm (Kraus, 2005). In order to acquire a better understanding of why and how I came to choose the methodological approach in this report, an introductory discussion will follow as it pertains to the paradigm that highlights the prominence of and is relevant to this study. Subsequent to discussing the appropriate paradigm of the research, this chapter intends to outline the methodology and research design used in this study. For the purpose of defining the study's research methods, a method of data collection and the associated analysis methods are discussed systematically.

4.3 Research Paradigm

TerreBlanche and Durrheim (1999) point out that a research process can have three main dimensions, including methodology, epistemology and ontology. Furthermore, they assert that a research paradigm is an all-encompassing system of interrelated thinking and practices that define the nature of enquiry alongside the above-mentioned dimensions. According to Olsen *et al*. (1992:16), a paradigm is a framework, structures, system or pattern, academic and scientific assumptions, values and ideas. In other words, the term paradigm implies a research culture with a cluster of assumptions, values and beliefs, which a research community correspondingly has with the conduct and nature of research (Kuhn, 1977).

Epistemological and ontological aspects relate to a person's 'worldview', which holds a considerable influence on the perceived relative significance of the aspect of reality. Important to this study's research methods approach, is the constructivist approach. According to Mertens (2005:7), a constructivist research approach aims to perceive "the world of human experience" and

demonstrate that “reality is socially constructed”. The constructivist researcher tends to rely on qualitative data aggregation methods, including analysis. It is likely for a constructivist researcher to tend to trust the respondent’s views of the circumstance under study, and define the influence on the research of their own familiarities and context. Through the research activity, constructivists tend not to begin with a theory, but prefer to develop a theory or a pattern of meanings inductively (Creswell, 2013).

4.4 Research Method

A comprehensive research design is required in order to facilitate every research project. For the purpose of this report, a qualitative research method with the correct methods was adopted to test the assumed findings. Therefore, qualitative techniques were applied to collect and examine data for the purpose of drawing conclusions and making recommendation for the maintenance as well as the mitigation of dolomite risk in Slovo Park informal settlement. This involved personal ethnographic engagement with the community, and with a dolomite risk practitioner involved in the preliminary planning studies of the proposed upgrading project. In this study, it was indispensable to assess the extent of the latter to the case study through interviews.

As pointed out in the earlier chapters, the overall aim of this research, beyond the Slovo Park Community, is to demonstrate that settlements should be knowledgeable about sinkhole hazards in order to make informed decisions, and take the appropriate actions to reduce vulnerability to risk in their communities. However, one of the tenets of this investigation is that hypothesis and solutions must not be generalised to all informal settlements from a situational knowledge of a few. To the best of my knowledge, to date this study was the first of its kind to examine this problem from an empirical standpoint.

The research design adopted in this report comprises an analysis of literature, South African geotechnical regulations and the South African disaster mitigation framework (2005). The theoretical contemplations and literature review helped in developing an insight into the problem and understanding around the challenges, particularly in this specific socio-environmental housing process. In this part, I provide a brief overview of the areas where dolomite is prevalent, some of which are discussed throughout this report, and indicate their relevance to my study.

I further examined the cause and different types of sinkholes, and anthropogenic effects on the physical environment. It is important to point out that it is not within the scope of this report to outline all the different techniques of determining sinkhole development, but only the commonly used ones that were incorporated in this paper. Relevant hazards topics were researched to further complement this research, and comprised of effective dolomite risk management framework and associated costs, applicable policies and strategies for geotechnical regulations. This particular settlement was chosen for the study because less has been written on informal settlements' anthropogenic impacts on geotechnical conditions and to date Slovo Park Community appears to be largely oblivious of risk related to development on dolomitic lands. It is because of this reason that the study is exploratory in a pragmatic paradigm, applying a qualitative method research approach through performing thorough, detailed interviews and series of dialogues with stakeholders of the community, and those involved in the upgrading project.

Therefore, given the socio-environmental dynamics, my level of engagement with the Slovo Park community and my commitment to integrate a theoretical dimension, Creswell's (2013:4) exploratory case method as "an approach to exploring and understanding the meaning individuals or groups ascribe to a social or human problem" ties together both the objectives and pragmatic realities of this study (Burawoy, 1998; 2009).

The research approach is explained in terms of my engagement with this community, and three extensions. The first extension involves the extension of oneself as an observer of the participants of the study. As the subsequent chapters will show, I was a non-participating observer. For pragmatic reasons and with the existing debates around the dolomite [tension about land] and upgrading of Slovo Park, issues of socio-environmental interactions are often difficult and sensitive to research on, as households usually do not want to appear to outsiders as if they are doing something overwhelmingly chaotic or illegal. Apart from offensive stereotypes attached to informal settlements, according to the some of the residents, this challenge is seemingly rooted in the idea of having to justify flawed actions and to be legally responsible and accountable for any damages caused. Therefore it took some time to assure the participants that whatever data acquired from them will solely be for the purpose agreed upon.

The second extension required was extending my interviews and observation across space and time. This implies extensively familiarising myself with the study setting and developing an insight on the impacts of geotechnical conditions and interventions in Slovo Park, as well as the perceptions of the

community on this subject. It is at this point that human insecurity from some of the community members translated into a disadvantage to the study. As certain residents were displeased with my presence and when they saw me, they did not seem as willing to talk to me. Some thought that I was a government official linked to the planning of the proposed developments in the settlement, but when they heard a different rationalisation about the purpose of the study, they were offended immediately. They stressed that if I am not bringing any developments "were are not going to entertain him, we have so many people coming to ask us questions but never aid us". Making contact with the community's leadership committee proved to be an important element in this research. With the receipt of the ethical clearance, they created a platform for my interviews by not only introducing me to the relevant participants for the study, but also validated the need for this research through mentioning that it is for academic requirements only.

The third extension explored the micro-and-macro dynamics influencing trends on the ground. This entailed recognising and analysing the role of the community and that of the municipality, and the private sector in their respective attempts to mitigate the risk of ground instability and to relocating households to geologic safe sites.

4.5 Qualitative Research Method

Hancock *et al*. (1998:2) assert that qualitative research aims to develop explanations of social phenomena and facilitate the understanding of the world we live in, and why things are the way they are. Its concern is the social aspects of the world and thus attempts to find answers to particular questions. Noteworthy in this study is that data gathered using the qualitative method are essentially in the form of words derived from documents and interviews, rather than just numbers. In other words, instead of determining 'how many?' this research seeks to determine 'why?' (Creswell, 2013).

4.6 The appraisal of literature

An on-going appraisal of the literature was performed for the duration of this report. Data collection was rigorously made from newspaper and journal articles, online publications, books, government documents and reports, and research reports. The appraisal as a research method serves various functions, including assisting to differentiate existing research from recent contributions to the subject matter, placing the study in a historical context, setting up the theoretical context of the

research problem, defining the importance of the research problem, and recognising relationships between practices and ideas (Greenland, 1987). In this research, the review of literature served a conceptualising purpose, by introducing the research and justifying its significance, as well as complementing the extracted fieldwork information. Empirical findings from the literature are incorporated in data analysis in order to offer a sound synthesis and interpretation of my research findings.

4.7 Data Collection Procedures

Data for this research project was gathered in August 2017. This aggregation of information was extracted from targeted interviews with members of the community and the relevant stakeholders involved in the proposed upgrading project.

The interviews were each conducted in about 30 minutes per each person using semi-structured interviews. Information compiled for analysis was largely qualitative in nature. I further used maps, photographs and sketches to document the activities and social processes which defined the socio-environmental dynamics of the study. The collected data have served as a basis for theories, policies and anecdotal evidence presented in the literature and context chapters in the analytical chapter of this report.

This study adopted a purposive sampling. This method is identified to be the most significant type of non-probability sampling. Using purposeful sampling ensures that the researcher interviews the required relevant population (Welman *et al*., 2005). I used this method to select a sample from community residents recommended by SPCDF Committee leaders. Nonetheless, I requested them to assign a demographic mix which would be representative of the community. The research activity interviewed a mix of nine community members and leaders, and a dolomite risk management practitioner.

4.8 Data Analysis

This research applies qualitative content analysis as an approach to analyse data. Wahyuni (2012) describes a qualitative content analysis as a process intended to condense unprocessed data into theme-based or categories on valid interpretation and inference. In addition, he asserts that this

process applies inductive logic, through which categories and themes transpire from the raw data because of the researcher's rigorous analysis (*ibid*.).

4.9 Delimitation of the Study

A few limitations were encountered where facts about the cause of water leakage from water-bearing infrastructure, which may facilitate the risk came to the fore. In order to evade this drawback I had to approach the community leadership to extract factual findings. Also at stake, is the existence of sinkhole phenomena in the area which major investigative organisations, such as the Council for Geosciences, Intraconsult and other entities, appear to have refuted. To validate the research's findings, I used Geographical Positioning System (GPS) coordinates to record the geographical locations.

Some of the respondents were strongly politically affiliated and so motivated that they began to refer the research to their respective partisans. In this way they were trying to restrict the study and access to information from other persons who belong to opposing political backgrounds, and thereby redirect the objectives of the investigation. During the field study, this research project encountered limitations where consistency in observing all variables in each household was not easy to uphold. This required me to retrace some of these happenings during transcriptions, after every interview. Taking into consideration financial and time constraints, I had to limit visits to the site to a maximum of eight weekdays of involvement. Due to urgent work commitments some of these parties had to reschedule meetings, and this effectively contributed to a lapse of the time allocated for conducting the investigation and report writing given that it was not simple to also re-insert myself as a researcher in this community. In addressing this, I had to make prior arrangements with some of the SPCDF Committee leaders and a CoJ official.

4.10 Research Ethics, Validity and Reliability

Ethics approval was obtained from the *Human Research Ethics Committee* in the School of Architecture and Planning, WITS University. Permission for the study was obtained from SPCDF Committee leaders. Due to the area under study being politically and socially sensitive, I ensured that the study was carried out professionally t all times. The interviews were, therefore, done through the application of moral principles and professional ethics for the purpose of protecting

both the researcher's and participants' interests. Immediately prior to interviews, potential respondents were advised about the nature and purpose of the study, the length of time assigned per each interview and a description of their involvement and rights.

All participants were requested to sign informed consent forms prior to being interviewed in acknowledgement of their willingness to engage in the study. Semi-formal, structured and focus-group interviews and dialogues were carried out on a voluntary basis. Prior to the commencement of interviews, respondents were informed that their participation is voluntary and that they may withdraw from the interview at any point during the interview or withdraw any given statement of potential risk from the interview. The confidentiality of all interviewees was guaranteed as no participants were personally identified in the final submission of the research report; however, pseudonyms such as 'interviewee 1' or 'respondent 1' will be applied. However, the SPCDF as a government entity may be identified to give credence to the study. All interview-extracted data will not be used for any ulterior motives or handed to a third party outside of this research. I was able to take notice of non-verbal behaviour to ascertain the validity of responses during fieldwork. With pride to show off their individual or non-state community-led intervention achievements, the residents offered me consent to take personal snapshots. This is to be archived on my personal computer, which is password protected. Hard copies such as interview notes, signed consent forms and audio tapes will be securely kept in a locked filing cabinet.

4.10 Conclusion

This chapter provided insights on the theoretical framework relevant to the literature of this research study. It outlined a detailed description of the research design of the study. The research adopted a phenomenological, constructivist approach, employing a qualitative paradigm. The chapter further discussed the examined methods of data gathering and justified the semi-structured interview methodology as the most relevant methodology to apply in order to attain the objectives of the research. Furthermore, the Chapter considered the data gathering processes and data analysis. It provided the ethical measures taken in conducting the study. The above-mentioned research methods adopted to gather data were used in the case study, as illustrated in the subsequent chapter.

CHAPTER FIVE
FINDINGS AND DATA ANALYSIS

5.1 Presentation of findings: Introduction

This chapter addresses the fieldwork phase of the research. The empirical data presented here outlines the social, cultural and household activities that have serious implications for the geotechnical conditions at the community level. The social and household data of the community as drawn from the interviews were varied. This enabled an understanding the resultant processes of human activity. The study categorises them into groups of livelihoods at household and neighbourhood scale, personal safety, problem solving and awareness. It then delves into both the micro and macro influences on residents' human behavioural reactions in interacting with the physical environment. In drawing on the empirical data and discussions in Chapters Two and Three, this chapter goes on to reflect on how two dynamics influenced *in situ* upgrading of informal settlement; the prominent one in this instance being the failure of government to make provision for much need education on how to prepare for, prevent, respond to and mitigate subsidence occurrences that can affect communities living on dolomite. The study centres on the functionality of informal settlements in the case study site of Slovo Park. The notion that sinkholes are becoming an increasing problem for communities residing on dolomite in Gauteng due to human activities is applied to investigate the dynamics of informality. Linking back to the discussions in Chapter Two, and the comments of Oosthuizen and Richardson (2011) that above all our communities are not prepared to deal with potential subsidence occurrences, the study further evaluates the relevant preventative measures, including comprehensive land and water use management, which can help reduce human activities' impacts on dolomite.

As Chapter Two has shown, Lidstone and Nielsen (1998) assert that education is the development of knowledge to empower people and encourage informed decision making. Drawing from this statement, I attempt to use similar logic in this Chapter to maintain that given substantial knowledge on subsidence formation preventative measures, this can serve as a catalyst to minimise human vulnerability on dolomitic lands. In other words, I use empirical evidence to demonstrate that informality is not simply a criminal, chaotic or sinister process for generating precarious livelihoods, however, through the undesirable treatment they receive from municipalities. This chapter goes on to argue that if education is used as a dedicated guiding

instrument to address the above issue, it can have the same influence on shaping these communities to better care for their surrounding environments.

5.2 Interviewees' socio-economic data

An overall mix of nine community leaders and members were assigned by the SPCDF to participate in the study. There were seven male and two female interviewees. Among these interviewees, five were heads of households and others were from outside the invited five households. The racial groupings of the sample comprised seven Africans and two Coloureds. The interviewees' age ranges were as follows; only one was between 50 and 59 years of age; four of them were within the age bracket of 40 to 45; two of them were within the 30 to 39 range; and the other two were between 25 and 30. Among the interviewees, only one had completed primary schooling and the remaining eight had completed secondary education. There was non-disclosure in terms of data relating to household income. The interviewees belong to various ethnic groups; seven were South African, one was a Mosotho and the other was a Zimbabwean national.

5.3 Socio-Cultural impact of various role players on dolomite

This section draws together the residents' *de facto* activities in their interaction with the dolomitic environment. In this context, it attempts to show that all human factors are linked to diverse survival strategies and access to livelihoods. Among others, these include land and water use. Section 5.1.2 attempts to distinguish human water and land use activation mechanisms, and to divide it into two categories to present an easy to comprehend overview of how people's social and cultural activities tend to exacerbate ground subsidence. The two categories involve those that affect land through excavating household or community landfill pits, and those that affect the hydrologic environment.

The results from the interviews indicate that socio-economic challenges are at the centre of socio-environmental issues. Almost all of the respondents in Slovo Park identified the socio-economic-environmental issues not only as altogether linked with their daily social, cultural and household practices, but rather as the most significant elements of their day-to-day community life. In this instance, it is seen from eight of the nine interviews that socio-environmental aspects are an integral part of socio-economic aspects and access to livelihood. A Slovo Park resident's (Respondent 4,

interview, 11 August 2017) comment emphasises this: “we don’t have ground cavities in our stand but we are selling *malana* (chicken intestines) to survive, because there are no jobs. So we dug a hole as you can see (figure 5.1b) to put water after washing [chicken intestines]. Since the toilet gets full fast”. In similar situations, dug pits outside household stands serve to dispose a miscellany of salons’ or barbershops’ fluids and solid waste. This disclosure led me to revisit and expand the research questions in this section to accommodate the economic aspects of socio-environmental dynamics.

Figure 5.1. Photos depicting typical anthropogenic excavated pits. (a) Off-yard rubbish dumping. (b). Backyard waste disposal. Source: Author’s photographs, August 2017

Stimulating urban livelihoods: how informal residents deal with socio-economic-environmental issues.

5.3.1 The dilemmas of domestic water discharge

In general, five of the respondents confirmed that they use the toilet for discarding extra water into. The other four had different alternatives, including throwing water in the streets, gardens and burrowed pits. The overall interview findings identified ongoing unemployment and urban poverty as the main contributors to socioeconomic-environmental problems. Among all the interviewees, seven concurred that the lack of formal employment causes households to utilise the available resources such as land and water to secure and improve access to economic prospects and better health, and acquire food for the family or the community at large. One of them (Respondent 1, interview, 10 August 2017) points out that:

> “Many of us don’t work. We survive by backyard rentals. So the more we are [with tenants] in single yard, we use lots of water and there’s sometimes no spaces to throw water around the yard. Then we

put it [domestic wastewater] in the toilets. This is a problem because they [toilets] simply [quickly] get full. But some house owners [landlords] tell their tenants to throw the [water] in the streets (Figure 5.2) so that it can dry faster and not [concentrate in] be on the same area. In my yard, I condemn it too. The pipe burst every time causing overflow because there are many of us using it and usually this happen when I am not there so no one wants to contribute money to fix it until I come back".

Three of the informants indicated that the situations have far-reaching impacts in terms of health beyond these households, as they can affect the community at scale by causing severe illnesses such as dysentery, diarrhoea and typhoid fever during windy and dry seasons, or even malaria. In support of this claim, the other interviewee (Respondent 3, 10 August 2017) mentions that "toilets get full and starts to attract flies and mosquitoes which bite us". This condition is rather displeasing as the seven informants claim to have no means to alter their situations, as they had no income.

Figure 5.2. Photos (a-c) exhibiting typical disposal of greywater on the roadside. Source: Author's photograph, August 2017

5.3.2 Urban farming: a danger to dolomite?

In the case of farming, four respondents indicated that they do productive, medicinal or ornamental gardening and that they do not control or monitor water use. Four others substantiated that they used greywater from domestic chores to water their gardens. Only one did not do any gardening.

The data show that the households depend largely on subsistence farming for income generation and food. As such, irrigated agriculture appears to be pivotal in poverty reduction in Slovo Park, although the benefits thereof were not quantifiable or documented. Some elements of the economic circumstance of Slovo Park coincide with Maxwell's (1995) statement that farming within African cities is becoming the most prominent source of food for the urbanites. For example, Respondent 4 (interview, 11 August 2017) commented that:

> "Slovo [Park] loves farming. [Virtually] Every house has a small garden, especially those who have spaces [unoccupied areas] in their yards to get food and make money. For instance, where I stay, we do grow spinach, cabbage, mealies [maize], especially now because [heading to] its summer, we are going to grow [maize] because the space is there [available] and there are no many tenants in the yard, you can be able to put [cultivate] a garden there [on the available portion of land]."

Additionally, Respondent 2 (interview, 10 August 2017) validates this through asserting that "people grow Mozambican *Morogo* (the plant is called "cale", is family of the cabbage and was introduced to Mozambique by the Portuguese) and sell as [informal] business". In figure 5.3 is a depiction of a lady who was excited to exhibit her garden patch of Mozambican *Morogo*.

Figure 5.3. Cultivated backyard small-scale farm. Source: Author's photograph, August 2017

Water use for agricultural purposes is known to be the source of human-induced ground subsidence due to its alterations of the hydrologic regime (Durand, 2007). These facts in conjunction with the comments of Slovo Park residents beg the question of *what the implication is of farming on water-use and for management in this area.* The interview data suggest that irrigation management is a complex process for small-scale farming. What instigated this question is the consideration of the sub-question of the research: how is the community in Slovo Park engaging with waterborne infrastructure? There is no consensus on the efficient handling of water when watering these gardens as all the respondents described diverse techniques for irrigating their gardens. The situation in Slovo Park is as Respondent 3 (interview, 10 August 2017) points out: "We use [grey] water after bathing and washing dishes to water the flower (ornamental) garden, we take out (sieve) those dirty things, like porridge, tomatoes, onion peels and put them inside a plastic bag and then you spill the water on [the garden] (Figure 5.4), and in the vegetable garden we use clean water from the [stand's] pipe".

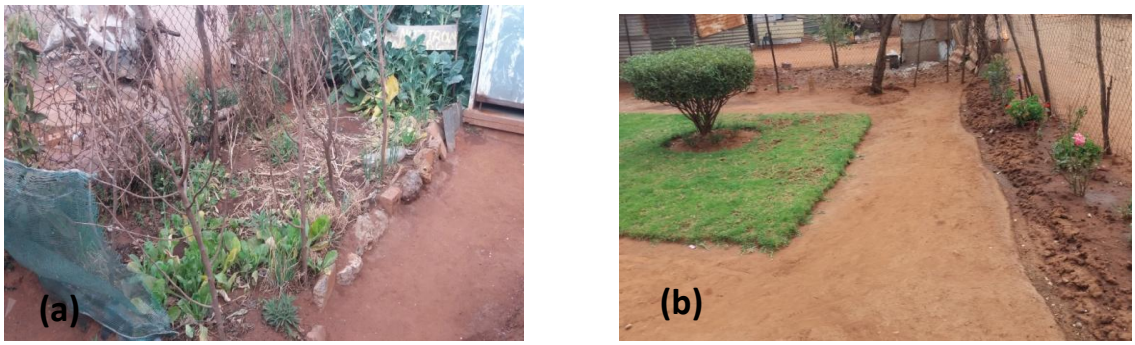

Figure 5.4. Informal consolidated gardens. (a) Productive garden for monetary gain.

(b) Ornamental garden irrigated through wastewater. Source: Author's photograph, August 2017

Predominantly, in households with burst and leaking taps the findings exhibit two common forms of highly automated irrigation by central pivot system methods. These include (b) level and graded furrow irrigation: where water is applied between ridges and allowed to concentrate there. (a) Localised irrigation: where water is applied around each plant and concentrates around it (Figure 5.5). Perhaps, what is important to capture from this is that these households connect a direct channel from the tap spot to these small-scale farms. These essentially become a link for leaking and overflowing water to seep straight into these gardens and cause further water concentration and latent and potential instability, and the resultant adverse impacts of the existing geotechnical conditions.

Figure 5.5. Typical informal strategic modes of irrigation. (a) Localised irrigation. (b) Level furrow irrigation. Source: Author's photograph, August 2017

From a 'food security and needs'-based perspective, the community of Slovo Park, with support from Community Works Project (CWP), has established a community, small-scale farm (Figure 5.6) on the northern margin of the area adjacent to the N12 Moroka Bypass with a goal of alleviating poverty and promoting sustainable livelihoods.

As the bulk of these interviews explain, the current political and economic climate embraces diverse ways of providing for the needy in the community, and farming was the foremost option identified. Among the respondents, four highlighted that farming continues to serve many crucial functions, apart from existing as a locus of food production in this community. Some functions include: prevention of further on-site landfills and providing residents with work opportunity on a voluntary basis. One respondent stated that "it keeps people busy, so that they don't sit and do nothing" (Respondent 1, interview, 10 August 2017). Nonetheless, the study found that the condition of landfills continues to deteriorate as many households still dump garbage openly. Even though Respondent 6 (interview, 11 August 2017) elucidates that "there's widespread scepticism among other people in the community, around this garden. People see this garden as backwards,

traditional, and unproductive. They associate it with rural [homelands]", this approach has clearly "brought [some] lasting benefits to the local people" (*ibid*.). However, this raises concern about the handling of water in the crop growing process. Despite the absence of proper or structured management of water in Slovo Park, Respondent 3 (interview, 10 August 2017) points out that "we don't have water management" but there is a high quality level of monitoring the application of water when watering this garden. They go on to state that "we use sprinklers [irrigation technique] to irrigate. We connect this from next door's [stand] tap (a tap from a household opposite the community garden). We don't want water running all over. They [CWP] tell us to save water. This is not only the duty of [SPCDF] *Block Committee Forum,* but all of us". Interestingly, this highlights that the inhabitants of this settlement are keen to learn not just passively, but to put the imparted awareness into practice. There is more to be learned from this revelation in relation to promoting awareness of preventative measures with regard to dolomite related hazards in this community.

Figure 5.6. Cultivated Slovo Park informal settlement communal farm. Source: Author's photograph, August 2017

As has been discussed, awareness creates space for involvement of local people in defining and providing a suitable and aligned answer to the challenge they are faced with. The research findings reveal that informal community leadership plays a significant role in this. SPCDF's Block Committee Forum effectively took the necessary steps forward to ensure good practices in water handling in this

community garden as advised. Furthermore, Respondent 2 (interview, 10 August 2017) mentions that:

> "At night people steal these pipes to go and sell them, and make money to survive [for sustenance], especially these young men who are lazy to work. When we wake up in the morning we find water flowing in the streets and everywhere unattended. Because the stand owner is not working it's going to take weeks to [procure financial means to] fix the pipe. These are the problems we are facing as leadership".

On average, all of the informants further mention that the outlined problems can be averted if the local municipality can introduce irremovable systems of water taps for their neighbourhood. Such illustrations, using connections that are based on relationships of socioeconomic need, begin to paint a picture of the impacts of livelihood endeavours on socio-environmental issues.

5.3.3 Use of agrochemicals or pesticides in crop production: a direct conflict to dolomite?

Overall, all of the respondents stated that they used neither herbicides nor fertilisers when farming. However, three confirmed that they apply pesticides around their households to exterminate pests. Specific farming practices have possible adverse consequences on the dolomite ecology that are so pervasive that they can be easily overlooked. Such activities include: the tendency of households to apply acidic agrochemicals and pesticides on dolomitic soils to ensure healthy growth of their plants (Durand, 2007). Despite the fact that some areas, including the informal, have some adopted rules or bylaws on the handling or treatment of water, the use of acidic substances is a risk factor, the importance of which escapes most residents of these communities. Of course, given the lack of knowledge of the mechanisms and substances that contribute to the wholesale destruction of the dolomite geology, and to the alteration of groundwater quality, residents are generally unaware of the impact these acidic substances may have. In order to kill pests, pesticides are often not only applied to kill pests, their application, significantly, is done carelessly without taking into account what the impacts will be not only on the social aspect, but on the physical environment as well.

Empirical findings from all the respondents show less use of agrochemical than pesticide substances in the aforementioned activities. All felt that the use of these substances in the presence of vulnerable children and livestock can be detrimental to their health. Respondent 4 (interview, 11

August 2017) links the non-use of these substances to health risk concerns, which parallels Respondent 2's (interview, 10 August 2017) assertion that:

> "Personally, I don't use pesticides in my house. We fear for the children safety and also the chickens. Many chickens use to die because of [consuming] chemicals. You can see around [other households] that people use a*masaka* [these are repellent, informal pests-proof nets; farmers use predominately maize meal or oranges bags to enclose crops as shown in Figure 5.7] to protect the garden fields".

However, six out of the nine informants confirmed that this does not mean there is absolutely no use of pesticides in households throughout the entire community of Slovo Park.

Figure 5.7. Example of domestic farming, and pests and livestock control nets. Source: Author's photograph, August 2017

Again, all of the informants pointed out that the use of pesticides is largely dependent on each household as some still use them to exterminate rats, for instance. What this essentially highlights, is that residents of informal communities can still be intuitive with regard to safety precautions and apply these measures vigorously. There is, therefore, no use of herbicides or fertilizers in farming. Eight of the 9 interviewees pointed out that to date no individual or household uses agrochemicals in the gardens. This aligns with what Respondent 5 (interview, 13 August 2017) mentioned: "it is very rare to find people using manure for gardening in Slovo [Park]. The soil is already fertile. People use *Ingca* (Xhosa word for dry pasture) or rotting cabbages and tomatoes [Converting vegetable and other plant-based waste into compost] to fertilize the soil. Even, where I stay, we have done the same. We dig [into] the ground and put these inside and cover". Such practices may sound

environmentally safe in comparison to the application of acidic chemicals. However, as the *Data Analysis* section will show, these are equally dangerous practices, particularly in the context of dolomite.

Given the wider context of Slovo Park's practices, only three of the interviewees acknowledged that some of the outlined activities are increasingly becoming dangerous for the dolomitic environment's stability, thus deepening vulnerability. Disturbingly, one of the other six participants, Respondent 7 (interview, 13 August 2017), argues that "nobody uses chemicals in the gardens, and I will not say manure is a chemical [implying that it is safer to use]". These perceptions on socio-environmental interactions, which encapsulate opinions driven by groundless theories lacking scientific basis, remain fundamental. What is critical about the vegetation decaying process is the contamination of water resources, including groundwater, and this is universally recognised as a major environmental hazard in dolomitic terrains. This reinforces the necessity of great caution for both the community and local government, considering the ever-increasing scarcity of water as resource in South Africa. The pollution of sanitized water poses a critical threat as water flows through conduits within dolomite into the underground aquifers (Mitchell, 1932).

5.3.4 The conventional ways of washing outdoors

In terms of using tap water for ablutions, seven of the respondents confirmed that they sometimes washing outside, whereas the remaining two responded in the negative, since they believed this practice interfere with their cultural values.

The negative effects of the farming situation, is not much different from the persisting cultural practice of taking a partial body wash, and doing laundry outside at the water tap, on a daily basis. In this context, all informants described this type of practice as associated with inadequate housing, where there are not sufficient rooms available for ablutions. This morphology is particularly apparent in any single-roomed shack household where a man or woman has to take a shower early in the morning before the household rises. In order to ensure personal privacy, they use the water taps to wash outside, away from the minors (Respondent 6, interview, 13 August 2017).

In addition, all participants indicated that where certain properties are congested with backyard rooms, generally there is no space to do domestic chores like laundry. One can also appreciate that some of these activities are nomadic or lifestyle choices. The interview data describe the use of

water taps to wash outside as a common practice by the addicts who are used to public ablutions. The informants did not share a similar view on the use of water for washing: four respondents indicated that because of variances from yard to yard, many use a vessel when washing their teeth at the water tap, especially when they have to attend to urgent matters elsewhere. The remaining five mentioned that it is mostly children and the homeless who tend to wash at the water taps because they are not bothered about passers-by. These washing related ergonomics do not only pose a problem with regard to sanitation and water conservation, but the effects of such practices impinge heavily on dolomite stability. The resultant chemically active greywater can infiltrate the subsurface and react chemically to dissolve the dolomite blanketing layer or bedrock. The lack of physical space draws attention to the study for understanding how housing density affects dolomite stability, risk and hazard zones; given the smaller stand sizes, coupled with a high population density and numerous tenant structures per stand in Slovo Park.

5.4 Considering the impact of informal housing units' densities on the '*status quo*' of dolomite in Slovo Park

This section considers spatial use in terms of quantity of dwelling units per stand, through interviews as well as drawings documented at the respondents' households, as a window for the further comprehension of the impact of land use practices on dolomite. The research has just described how the community engages with its habitat. Now it questions, whether, as Kirsten *et al*. (2009) mention, certain construction layouts on dolomitic risk surfaces activate the collapse of pre-existing conduits through changing the surface water ground inflow. For instance, as observed while walking during the interviews, building closely spaced or impermeable structures can change the way in which water naturally infiltrates into the ground. Five of the respondents were the heads of households, and they confirmed that they had multiple structures where either generational and extended families or tenants were living together. The remaining four were tenants of different households.

The drawings in Figure 5.8 demonstrate how households arrange their living spaces in various ways, illustrated by either a single or multiple units on a single delineated stand. In this way, all of the respondents described that during rainfall or when disposing of waste water, water is diverted through a restricted runoff area, resulting in high concentration and percolation at a single point. This triggered the need to further examine how dwellings' layout conditions, in terms of density, erf sizes and foundation types, influence households' social, cultural, and daily household activities. The

concern among all the interviewees centred on overcrowding, and the distance between detached dwelling units in many of the yards.

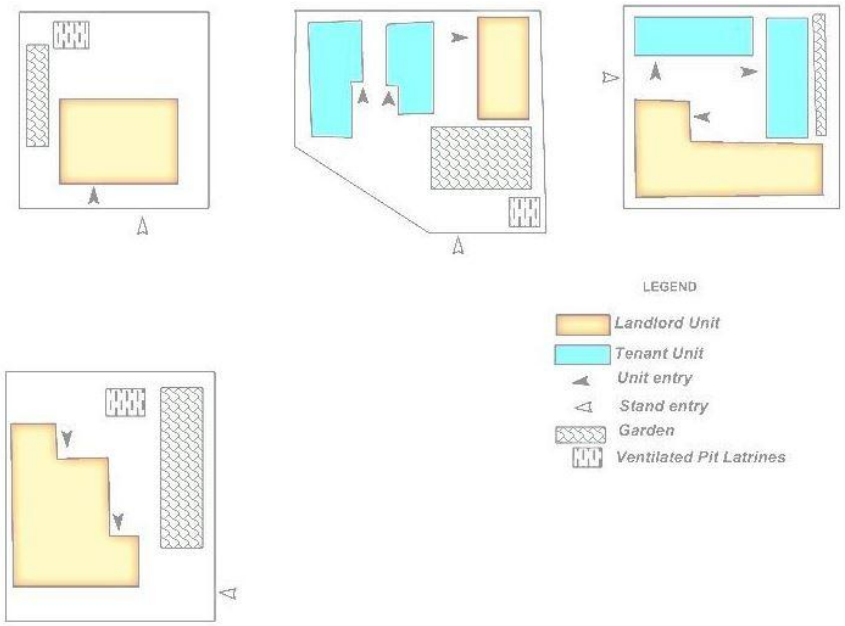

Figure 5.8. Typical Slovo Park households' demarcated plots with single and double dwelling units. (Source: Own Construction, Aug 2017)

All of the respondents pointed out that overcrowded and yards with high density are inclined to impede the natural flow of water within that space. As a result, water discharging from the roof of the house during rainfall flow along and concentrate at the Ventilated Improved Pit-latrines (VIPs). This record is based on this quote: "in Slovo [Park], number [negatively correlated with household size and backyard rental units] is the main problem" (Respondent 8, interview, 14 August 2017). As noted earlier in this report, the staggering tenant population figure of 2 658 out of 3 734 households sitting on only 1 469 stands of a size of 300 m^2 per stand (CoJ, 2017), strongly underlines the great number of single detached units, and the short average distance in metres between dwelling units per stand. As can be observed in this settlement (Figure 5.8), fitting multiple detached units within a stand requires varying layout typologies to maximize every portion of an open space. From a spatial viewpoint, the dwelling density classes in this area largely encompass double and multiple housing clusters on each stand.

As Chapter Three shows, the Inherent Risk Classes assigned to Dolomite Hazard Zone 1 (DHZ): D1 of the study area are 1 and 3 (*ibid*: 6). This implies the area can be developed at moderate residential

densities of twenty to sixty units per hectare of 300m^2. All of the respondents confirmed that in the current development form this range has been exceeded, creating further congestion of dwelling units per hectare, and in their respective yards. However, it can be noted that this "number" mentioned by Respondent 8 suggests that given a larger number of built units and inhabitants residing within one stand, the engagement with water fundamentally becomes extremely adverse. While this statement may be partly true in certain scenarios, Respondent 7 (interview, 14 August 2017) refuted this claim by holding human behavioural considerations and lack of social awareness responsible by asserting that:

> "The alarming problem is that people sometimes have different family practises, regardless of whether they are less or many. Even if you tell them to use gutters around the house to discharge roof water far from the foundation they will still prefer digging open ditch along the foundation to serve as a channel for greywater and redirect roof water flow away from the structures concerned but this instead causes further concentration".

While caution can be advised in considering the quarrying of open ditches along foundations for water passage, this practice coupled with the aforementioned domestic techniques exhibit the diversity in which people function within their own space. At this point, the study gains essence from the notion that a further understanding of the potentially dangerous practises of informal communities, among other elements, is needed prior to administering dolomite risk mitigation interventions and awareness training. This can be done in order to help fully address all these typical and largely overlooked practices. It is based on the premise that what is at stake is the community's vulnerability to dolomite risks, which largely flows from such practices. The risk of sinkhole occurrences in this area may be greater due to these typical and seemingly trivial actions at play, despite the fact that the area is characterised by a medium inherent susceptibility to sinkhole and subsidence formation with respect to ingress of water. This is proved by the relatively abundant cavities in the surroundings of this settlement.

5.5 The appearance of a significant number of small dolomite cavities

With regard to the impacts of ground cavities, six respondents were very concerned about susceptibility to cavities of the ground they live on, whereas two others were affected by existing cavities. Only one was unconcerned with the existence of such phenomena.

The Council of Geosciences and the City of Johannesburg to date poses no record of existing sinkholes and subsidence in the Slovo Park precinct. The empirical observations of this research validated this. However, an abundance of unrecorded hollow gaps are to be found on the far western margin of this settlement. The large cavity in the South-Eastern section of Slovo Park is an example of a compound cavity (Figure 5.8), exhibiting two distinct innermost subsidence contours, and yielding a count of two overlapping cavities. Unfortunately, these geotechnical reports only show the non-existence of major phenomena, and fail to provide any additional data on these small cavities or their scale of severity. The field reconnaissance revealed that damages from cover-collapse cavities are also common in the area. Six of the respondents mentioned that residents address such occurrences at a community-level, and as such their concerns have not been registered since they are not reported to local authorities or the media. Illustrating this is Respondent 3's (interview, 10 August 2017) assertion that:

> "this place doesn't have big [sink] holes but there are few small holes [cavities] developing every time especially when we try to close the previous ones. These problems led to a woman falling into a hole during night-time on the next street and breaking her leg about two years ago. And sometimes cars get stuck in these holes, especially at night".

In order words, what is implied is that there is a persistent propagation of hollow gaps.

Table 5.1: GPS Readings of the uncovered cavity in Slovo Park informal settlement. (Source: Own Construction, Aug 2017)

Type of structure	Size of structure (metres)	GPS Readings	Location
Ground Cavity	The diameter measures at 1,37 m	Thurs, 10 Aug 2017 Latitude: 26, 306616°S Longitude: 27,90133°E Altitude: 1543, 0 m Accuracy: 3,0 m	Located in Moletsane Street adjacent to the Cavendish Road.

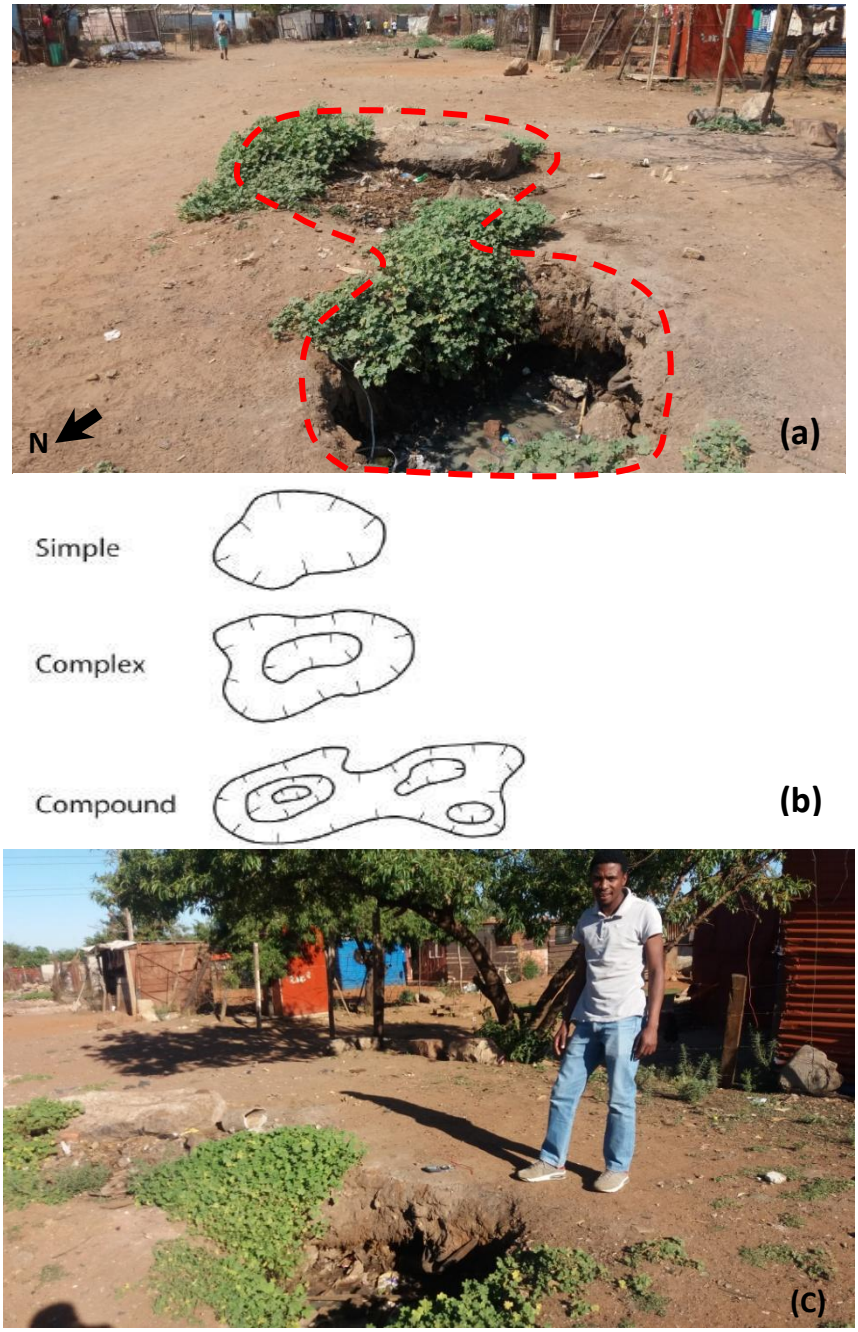

Figure 5.9. Propagating compounded cavities in the South Eastern section of Slovo Park informal settlement. (a) Cavities are marked by the presence of depressions and ponds. (b). Examples of the three typical cavity forms documented in the area of study: simple cavity-defined by a single depression contour, complex cavity, and compounded cavity-defined by multiple depression contours. Source: (Modified from White, 1988). (c). Using human size as a reference to document the approximated size of the cavity. Source: Author's photograph, August 2017

The impacts of the movements of the ground cavities may in future cause severe adverse effects through the generation of subsurface cavities' expansion. As observed on the walks, these propagations could be influenced by the breakage of buried water pipes, causing internal erosion. The spatial distribution of these cavities or loose grounds where the strength was decreased due to erosion, were along the illicitly installed pipelines. In supporting these observations, Respondent 9 (interview, 14 August 2017) indicated that:

> "normally where there's a burst pipe particularly in the streets not anywhere near someone's yard, the *Jozi@Work* [a government entity responsible for delivering of municipal services such as wet infrastructure and refuse collection] people are responsible for fixing of that pipe. But as usual they take a while to come, then, the SPCDF's *Block Forum* compels the residents of the respective block to contribute funds to purchase piping joints and fix it. Commonly some of the residents refuse to make a contribution".

As pointed out earlier, this leads to the formation of cavities as a result of localised seepage which developed along the closest path from the surface to the fractures in the pipes. Four of the respondents acknowledged that this phenomenon is further evident around the VIP toilets. Seven of the respondents commented that poor households with leaking water taps who can barely afford repairing equipment and workmanship, resort to applying the water bucket *fill-up* and *pour-out* strategy (Figure 5.9). This water is discharged into the VIP toilets. Consequently, the toilets become full quickly, inducing internal erosion accompanied by the appearance of subsidence or hollow gaps behind the toilets (*ibid*.).

Figure 5.10. Intervention practices: households using buckets to avert leaking tap water from spreading through the yards. Source: Author's photograph, August 2017

All of the respondents constantly voiced their concern over issues of personal and children's safety. The manifestation of hollow gaps behind the toilets has become particularly dangerous for the children's safety. All indicated that cavities often provide habitat for dangerous species of animals, for instance, snakes. Only one respondent stressed that informal residents mostly impacted by the existing cavities tend to be in acute danger of snakes. In light of these revelations, informal settlements are subjected to the worst of the City's socio-environmental issues, which socio-environmental practitioners, disaster managers, and housing officials often treat as too trivial to grapple with. Yet, these issues have severe impacts on the inhabitants concerned. This study, to a great extent, confirms the failure of some relevant stakeholders to record pre-existing cavities in this area's surroundings. All respondents felt that the risk of exposure to potential hazards from cavities is a community concern which requires bottom-up responses rather than interventions, awareness, and monitoring from geological agencies, disaster managers, socio-environmental practitioners, the Provincial Housing Department and other stakeholders.

The argument for a bottom-up move is essential, and one agrees that it can be an advent of real collective change. However, ignorance of the cavities by experts has somewhat influenced informal residents to overlook these problems as well. Again, all confirmed that the persistent occurrences of

ground cavities cause the community to eventually ignore them when they remerge after sealing up the preceding holes. This calls for consolidation of community experiences and technical knowledge, while at the same time emphasising the need to assemble technical, and non-technical, skilled stakeholders in order to adequately address issues related to residing and developing on dolomite, and further explore the potential synergies of coordinated interventions. The concept of collective roles, action, and empowerment over broad socio-environmental issues, increases the awareness of dolomite hazards. They help to articulate unrecognised and potentially dangerous practices, allowing residents to find technically effective and appropriate mitigation and coping strategies. This will further encourage dolomite affected communities make better decisions by identifying and quantifying impending hazards, and align such risk minimising actions with Government and local municipal objectives. This will effectively cause residents to realise themselves as solutions, and not just problems, instigators, or victims of it.

5.6 Accompanying hazards awareness: are informal residents primed for subsidence occurrences?

The settlement's upgrading is a contentious struggle, and conflicts have openly facilitated awareness about the existence of dolomite in Slovo Park. This record is based on the view that when asked whether the respondents were aware of the case of dolomite, all responded in the positive. They indicated that Intraconsult's geotechnical consultants provided critical awareness about dolomite in 2007. This awareness is in response to and is informed by consideration of Section 151 (1) (e) of the Constitution, which effectively advocates for persons affected by dolomite to be informed in terms of a Dolomite Awareness Plan, or similar plan. Not all of the respondents were acutely aware of the relevance of the matter. The results indicated that even with active awareness of the area's dolomitic condition, only five were aware of the negative implications of this condition on anticipated physical developments, whereas two showed knowledge of the implications of some of their household practices on this condition, and none were aware of how to deal more effectively with potential and domestic sinkhole triggering mechanisms.

The next section will accordingly elaborate on findings drawn from the evaluations and connections with the theoretical investigation.

5.7 Data Analysis

This section reviews the findings of the research as described above and related discussions. In reflecting on the cluster of interviews, there appears to be a consensual understanding that the key emerging factors and themes that deserve consideration are:

- water use and judicious control;
- unsafe socio-environmental interventions addressing farming issues and lack of space within demarcated stands;
- the existing ground cavities; and
- awareness

This research acknowledges that addressing these factors and issues appropriately may carry more weight as far as the application of special geotechnical techniques in construction is concerned when living on dolomite. With the adopted coping mechanisms and use of the resources at their disposal, the Slovo Park Community has managed to reduce and avert water leakages, quarrying of ponds and wells, and the application of agrochemicals in gardening, but not without these challenges:

i. the excessive use of water in gardening (economic concerns are the main reasons why residents expand planted areas and increasing watering frequency);
ii. households with many family members or tenant units use large quantities of water and lack space to discard wastewater;
iii. the disposal of greywater inside the VIP toilets, thus causing an inundation and concentrated water ingress;
iv. the frequently bursting of unprofessionally installed water pipes and the accompanying lack of financial means to fix them;
v. customary practices of body scrubbing outdoors, at the water tap spot; and
vi. recurring storm water damage in rainy seasons.

5.7.1 Water use and judicious control

The overall results highlight that the general key issues of concern around potential development of dolomite hazards in this settlement are attributable to the inappropriate handling of water. There is a strong consensus among all respondents about the urgency of much needed awareness about the

underlying impacts of the existing water handling practices on dolomite. The majority of the interviewees are under the impression that the indifferent attitudes by residents towards water use contribute to the cause of environmental and health problems, and incessant vulnerability which affect the habitat and inhabitants themselves. Geocaching (2014) concurs that beyond posing danger to humans depending on water for irrigation and consumption, these threats remain a problem to the associated ecosystem.

Few of the respondents felt that discharging fresh and greywater inside the toilets was a waste as the human waste-amalgamated water will reach groundwater and pollute it. This is of interest if taken in parallel to the argument of Hyland *et al*. (2006) that the unfortunate misunderstanding which exist among people living on dolomite is that human solid waste will be decomposed in the presence of bacteria in the soil and separated out by the substrate prior to reaching the groundwater that is required for consumption. As was discussed in Chapter Two, this misconception serves as a source of groundwater contamination, and therefore also for accelerated dolomite bedrock dissolution due to alteration of groundwater's pH.

The majority of the respondents claimed that the community was not wasting any water. However, in all these claims the analysis of the overall results illustrates that the unfortunate reality leads to a situation where households have to deal with the resultant negative effects themselves, without the benefit of any external aid. The concept of insurgent citizenship is understood as a way of articulating informality's role as a mode of bottom-up development. As such, insurgency should emphasise the transformation of dangerous water handling practices at a community level with greater efficacy as the first step in defining their role in a bottom-up decision making. Instead, transparency should be embraced about dangerous practices pertaining to inappropriate engagement with water in order to change residents' attitudes and perceptions towards dolomitic terrains.

5.7.2 Unsafe socio-environmental interventions

The overall responses echoed the view of Monto *et al*. (2005) that even though community-based interventions are instilled with the potential to enhance livelihoods, it remains challenged by complex limitations and misconceptions. The research indicates that residents are, without proper external interventions, adopting such means as they see fit to reduce their infrastructure and services backlogs, particularly by providing or informally expanding waterborne services, increasing

housing stock by means of backyard rentals, and food services through small-scale farming. The majority of the interviewees indicated that not only do these self-help approaches support local housing solutions but that it also have long-term benefits. These reflections displayed the way in which some of the respondents considered such approaches to be innovative or able to yield solutions. This was captured in how they talk with pride about the interventions having significantly contributed to the consolidation of their living spaces rather than simply waiting on government's disappointing time lags and unfulfilled promises on developments. However, few of the respondents recognised the serious drawbacks associated with these interventions.

5.7.3 Lack of space within demarcated stands

Backyard shacks are impractical in this settlement due to the area's dolomitic nature. An interesting fact produced by the inquiry was how respondents viewed congested spaces or yards with more dwelling units as the root cause of reduced surface water permeability, which promotes an increase in velocity and volume of runoffs. In the review of *Approach to sites on dolomite*, Heath *et al*. (2007) warned against densification and its standard setbacks on dolomite, taking into consideration that constructing impermeable structures changes the way in which water naturally soak into the ground. Again, only few of the responses concurred with this advice through indicating that instead of wide dispersal of runoff, water gets diverted, concentrating and causing ingress in one location.

In all the documented cases in this research, households with burrowed pits on their properties were conducting some form of informal business, and the respondents indicated that the pits are essentially used for discarding greywater and household waste. Another misconception drawn from these responses is that wastewater is essentially disposed far from built units. In other words, they imply that an increase in distance from their properties to where large quantities of water is dumped, there is a guaranteed reduced impact. This was readily apparent in how some of these households dug the pits outside their yards. Against this, and by way of illustration, in dolomitic systems water percolates *via* existing voids or cavities, dispersing laterally in various directions, causing much erosion and cavity enlargement in existing conduits (Oosthuizen and Richardson, 2011). The highlight of this is that the impacts of these man-made wastewater ponds are not necessarily dependent on distance, but rather on subsurface voids or fissure channels. In addition, even if distance was a determining factor, these pits are not positioned at a distance that is so far removed from their structures as to possibly avert any potential hazards.

5.7.4 Farming issues

It can be recognised that while urban farming was highly commended throughout the findings of the study for its significant contribution to informal residents' well-being, and extends beyond material gain, the interview data still underlined certain setbacks associated with irrigated agriculture.

All the respondents deemed it not a waste of water as a resource to use domestic water or greywater for irrigation purposes. However, the use of wastewater for irrigated agriculture is a very dangerous activity on dolomitic terrains. This water infiltrates groundwater more rapidly than in any other environment (Hyland *et al*., 2006). An interesting fact is that wastewater has detrimental effects on human and animal health given that the chemically active substance-amalgamated water could infiltrate groundwater prior to a sufficient time lapse for substances to breakdown into less harmful components (Durand, 2007).

The majority of the respondents highlighted that planting vegetative buffers further helps in regulating run-off through facilitating absorption of run-off by the ground, thereby reducing impermeability. The general understanding is that increasing permeability will drastically reduce the velocity and volume of run-off. Furthermore, respondents indicated that households without gardens turn out to be swampy and occasionally flooded during rainfall. However, in dolomitic terrains change in run-off leads to sinkholes or subsidence forming in zones where there is an unnatural excess of water (Geocaching, 2014), particularly in these cultivated and grassland areas. It is a stark reminder that while the benefits of vegetative materials can be linked to catalytic measures of reducing run-off and the resultant flooding by improving drainage patterns and the absorption rate of surface water, one cannot ignore their profound impact on dolomite stability.

The majority of the respondents highlighted that they use plant-based manure such as rotten vegetables to nourish the soil. All felt that it is a safer practice than using agrochemicals. When considering the geochemistry of dolomitic soils, it is worth drawing insights on the effects of decomposing plants debris or humus. Humic acid or humus is considered a layer of decaying plants at the top of the soil (Mitchell, 1932). Minerals from this layer contribute to formation of soil and as a result affect the pH. This happens through the decomposition process in which organic, vegetation materials are altered into inorganic chemicals, among others, such as calcium, phosphates, sulphates and nitrates (*ibid*.). Through the process of leaching, these chemicals are carried across the soil profile by the action of water moving down. As already illustrated in Chapter Two, calcium is one of

the minerals which are most easily leached from the top soil layers. Thus, its removal causes the top soil layers to be more acidic. The rate of acidification is regulated by the inflow of water into the ground, like irrigation processes and evaporation. A higher surface water inflow into the ground will tend to result in an increased soil acidity, thus affecting the composition of dolomite (calcium carbonate ($CaMg(CO_3)_2$)) causing dolomite dissolution ($CaMg(CO_3)_2 + 2\ H_2CO_3 \rightarrow Ca(HCO_3)_2 + Mg(HCO_3)_2$) (Oosthuizen and Richardson, 2011). In other words, water seeps through the soil, absorbing carbon dioxide and reacting with decaying vegetation, and as a result the water that reaches the soluble rock is acidic enough to erode the rock beneath the surface (BBC News, 4 March 2013). The presence of ample solution cavities in this settlement is evidence that this process is at work.

5.7.5 The existing ground cavities

This research has identified and documented several cavities on this settlement ground. Identifying the size and frequency of the previous and existing cavities are fundamental steps in forecasting where new ones are likely to form (Gutiérrez, 2010).The respondents indicated that subsequent to residents having sealed up the cavities, new ones suddenly re-emerged within close proximity to the previous ones. It is on this basis that the interview data begin to articulate that it is the dynamic between the vulnerability associated with solution cavities risks, and other various associated detrimental environmental and health problems emanating from poor water handling practices that is at stake in Slovo Park. The overall interview data highlighted that the existing pressure on urban development within dolomitic zones are not just a concern from an infrastructure point of view but for the safety of residents alike. Certain of the respondents emphasised that the emotional toil of living with persistent fear and anxiety in an area that develops propagating cavities within its surroundings is impossible to quantify, yet it have adverse effects on the residents concerned.

As shown in Chapter Two, dolomite terrains are extremely fragile environments, and as indicated by the fieldwork findings above, are affected by anthropogenic actions such as intense dewatering activities. These water use activities result in degradation of the surrounding land (Berkes *et al*., 2008), thereby creating or expanding cavities, fissures and voids. The situation in Slovo Park has deteriorated to such a degree that solution cavities are becoming active, forming one after the other within the same radius of less than five metres. It is on this basis that this research argues that while sinkholes have not materialised, like the cavities, these phenomena can remain undetected for

several decades, and then suddenly and dramatically open up, instantaneously forming extremely large openings while swallowing all objects around them.

5.7.6 Awareness

This finding certainly answered the problem statement outlined in Chapter One, as follows: What awareness exists among residents and leadership on how sinkholes are activated? In addition, this objective was met: to assess awareness among residents and the leadership about human activities that could trigger the development of sinkholes.

The results of the study indicated that almost all interviewees were unaware of how dolomite stability is affected, and the resultant sinkholes are activated. Certain of the interviewees knew about some of the human activities that trigger sinkholes, and they were emphatically concerned about water use activities which pose the biggest immediate threat to ground stability. In addition, none of the respondents were knowledgeable about mitigation strategies that would help minimise the probability of sinkholes, prepare them for future occurrences and better protect their settlement. Respondents who seemed to be unaffected by the burgeoning impacts of geotechnical conditions, reasoned that talk about geotechnical challenges is used as a reason for undermining the *in situ* upgrading of Slovo Park.

The theme that arises from this discussion is that none of the interviewees know how dolomite related hazards develop or are exacerbated. Even though the community was made aware of dolomite, the awareness was not meaningful enough to address mitigation, response and management strategies that can help alleviate losses and damages related to dolomite hazards.

The understanding of the current and prime focus in the planning of developments in Slovo Park, is that raft foundations will be used for each built unit per every 300m^2 plot as the ultimate solution to reducing sinkholes risk. The socio-economic climate of this area, which is has been destroyed by high levels of unemployment and poverty, does not favour this approach. It is on this basis that one concludes that this recommendation is unsustainable as the condition of one structure per 300m^2 plots is less likely to remain this way before residents again start erecting backyard units for monetary gain and survival. This awareness can empower communities to participate in a meaningful way in safeguarding their dolomitic habitats. Nielsen and Lidstone (1998) concurs with

this statement by pointing out that awareness is the development of knowledge to empower people and encourage informed decision making.

5.8 Conclusion

Overall, the above sections have drawn on theory discussed in Chapter Three to demonstrate how the informal dweller's needs-based practices, coping mechanisms and informal institutional arrangements involving non-governmental aid, indirectly generates hazards, and therefore stimulates further vulnerability within their own habitat. The few documented illustrations of this process has started to show how human settlements impact geotechnical conditions, and their surrounding environs. Their methods for risk mitigation in other instances could be deemed useful for adaptation on a much broader scale. This requires proper buy-in from the government to consolidate the potential intrinsic to these approaches when considering the safety risk to other settlements of similar situational functionality. A DRMP remains a much needed tool in this community to manage and cope with the inherent geotechnical conditions.

A conclusion is arrived at, and case specific recommendations are made in the next Chapter to provide the CoJ and other relevant stakeholders with concrete solutions that will improve the "management of developments on dolomite". This in turn will have a positive influence towards meeting the SDGs' Goal 11, which essentially advocates for "more inclusive, safe, resilient and sustainable cities [housing] and communities" (UN Habitat, 1996).

CHAPTER SIX
CONCLUSION AND RECOMMENDATIONS

6.1 Introduction

This Chapter draws on the conclusion and recommendations of the preceding study. The body of work is examined with the aim of extracting findings which can contribute to the larger discourse on socio-cultural and household practices that are adversely consequential on dolomitic informal settlements.

6.2 Hypothesis

It is evident from the above discussions that the Slovo Park Community does not fully comprehend the complex hazards associated with dolomite, nor how the associated hazards are triggered with respect to human behavioural activities. Most of the socio-cultural and household practises of all of the respondents contributed to susceptibility to ground cavities and other detrimental environmental problems. The Community will not be able to reduce, let alone prevent, geotechnical risks with their individual and non-state led community interventions unless legislative actions, better regulations and measures for the creation of awareness are formulated to prevent problems from recurring, particularly while planning *in situ* upgrading projects.

6.3 Conclusion

It has become necessary, in the case of residential development, to utilise the dolomitic land in Slovo Park informal settlement. The geotechnically surveyed available dolomitic erven, like any other dolomite areas in South Africa and globally, is variably constituted by two inherent risk zones of dolomite; one which can safely accommodate various types of development, and the other land portions which do not permit for any development. Despite the existence of a dynamic awareness of the presence of dolomite among the local authorities, planners, dolomite risk managers and other relevant stakeholders, the research concludes that the community is unaware of how to mitigate sinkholes and subsidence occurrences from developing within their surroundings. This is so, particularly, when considering some of the dangerous social, cultural and household practices associated with dewatering activities that affect the cavernous dolomite. To the chagrin of these

decision makers, South Africa is perceived to be ahead of its counterparts in terms of risk management of development on dolomite terrains (Council for Geosciences, 2009).

The necessity to effectively administer geotechnical risk mitigation tools in informal settlements, as opposed to their formally planned counterparts, has been met with great reluctance by the appropriate decision makers. While sinkholes have not manifested in Slovo Park, active and propagating small scale cavities are prevalent, and have critically subjected the community to increasing and incalculable vulnerability. Disturbingly, the formation of the inherent cavities is exacerbated by dangerous human behavioural practices, which remain unnoticed or unchanged among the residents. While there is a sustained period of limbo in making provision for formal developments, there is a growing threat from these practices against the stability of dolomite, groundwater quality, the safety of inhabitants and homes, and other valuable infrastructure. Unlike the distinction made on safe and unsafe developmental zones, these threats affect the entire community, and areas beyond Slovo Park.

The increase in population, either through family expansion or backyard letting, simultaneously intensifies the use of water resources, densification and alteration of water courses, thus increasing the probability of an inherent susceptibility to sinkholes and subsidence manifestations. Community livelihood improving strategies and environmental challenge coping mechanisms were defined qualitatively, using pragmatic experiences within the area. In addition, the respondents' understanding of dolomite geomorphology and hydrology, as well as the significant role waterborne infrastructure play in determining subsidence manifestations, were also established. These activities appear to trigger numerous environmental and health issues including surface run-off and, at times, become the cause of localised flooding, the formation of ground cavities, and contamination of groundwater. Human activities, predominantly dewatering activities, are at the heart of all these problems. , Even the aforementioned problems carry a burgeoning threat to many lives and buildings in this area. Additionally, the recording of sinkholes but disregarding or overlooking the existing small-scale cavities, maintains the status quo on vulnerability. On the other hand, it provides an opportunity to recognise that even with all the conducted investigations, there unfortunately is no technique or technology which can detect a sinkhole with 100 per cent accuracy.

Given the general lack of understanding of the risk related to sinkholes and subsidence development in informal urban areas, which is attributable to limited information sharing, understanding and education, informal dwellers are not aware of the shared responsibility they hold in managing the

risk. The study recognises the gap that exists in literature and geotechnical interventions around legislation, standards and procedures for the management of developments on dolomite. Instead, energy and resources are extensively invested in specific recommendations for foundations and wet services designs. Likewise, unlike in formal or affluent suburbs where there are fewer socio-economic challenges to address, in the face of the dilemmas of subsistence and unemployment, informal settlements are confronted with the challenges of finding ways necessary to thrive and survive. These communities are simply surviving, leaving very little room to afford the rehabilitation of sinkholes.

The highly prioritised technical resolution in the case of dolomite is to de-densify congested housing units within the delineated erven in informal settlements. It can be appreciated that residents generate income through the practice of shack rentals or backyard letting. There is a greater probability that the de-densification approach will not serve as a long term solution to mitigate dolomite-related hazards, as residents will most likely resort to utilising the available spaces within their 300m^2 stands to construct backyard units, thus causing further congestion and creating conditions for sinkhole development over time. In the case of primary dwellings and backyard units, informal residents can neither afford expensive raft foundation designs, nor the required dolomite stability investigations to have their properties examined for sinkhole activities prior to development.

Development on dolomite requires careful consideration of all possible variables and, therefore, the reality described above necessitates not only the development of engineering solutions to the problem but the implementation of these to the letter:

- proper maintenance and monitoring plans for wet services to prevent concentrated water ingress;
- installing waterborne infrastructures far away from the housing structures and gutters around the housing structures to discharge roof water far away from the house foundation;
- substitute illicitly installed sanitation and water pipes by pipelines constituted of several joints with flexible replacements comprising of less joints, and
- avoiding the use of detergent-mixed greywater for irrigation.

While gardening often makes things worse, employing safe irrigation techniques like sprinkle and drip water systems can ameliorate the severity of sinkholes developments, while simultaneously

promoting surface and groundwater conservation. These cost effective, sustainable land use and preventative strategies adopted to minimise vulnerability to risk, are often not easy to apply for the local-authorities and other relevant decision makers, especially in the context of informal settlements, largely due to the costs related to upkeep. In essence, it is regarded as irrational to spend fiscal resources on intangible things such as vulnerability, which affects residents' emotional well-being and sense of security, of which the benefits are never immediately palpable. The recognition of disastrous events, led by sinkholes with their associated cost of rehabilitation, leads one to appreciate the benefits of prevention, rather than suffering the costs related to repairing sinkhole damages, let alone the spectre of injury or death.

In addition to these suggestions, the use of proactive dolomite risk management plans may become a viable and long term solution in the context of the sought *in situ* upgrading, since it minimises the overall risk of vulnerability, and can lead to the uplifting of livelihoods considering how SANS-1936 Part 4 exists but is rarely ever enforced, especially not in informal settings. While households are expected to deal with the financial burden incurred in the case of sinkhole manifestations, it is unlikely that they can reactively pay out of pocket for hundreds of thousands of Rands' worth of rehabilitation. To date, in South Africa there is no insurance policy to help defray the costs or entirely address sinkhole repairs. In the wake of this, government will be held accountable for sinkhole damage and associated costs. As far as the community is concerned, this calls for the local authorities, policy makers and developers to recognise the DRMP educational and training programme's worth with regard to controlling human activities that exacerbate sinkhole development.

6.4 Recommendations

The prevention and tackling of dolomite failure in informal settlements takes little precedence in the CoJ. This research recognises that investigating and establishing dangerous household activities at a community scale proves imperative for the mitigation of future dolomite instability. The subsequent suggestions are critical for the detailed understanding and mitigation of sinkholes development.

Understanding the dolomite environment, and being knowledgeable about human factors or behavioural practices that influence hazards' manifestations are the initial steps in determining related risks, preventative and management guidelines and strategies, which assist in eradicating or minimising the manifestation of future subsidence occurrences. Development practices that vouch

for the safety of people, following the mandate given by the South African Constitution to ensure this right is achieved, and comprehensive planning for water and land use that considers dolomite risks related to susceptible areas, will help foster safe and sustainable human settlements.

Once there is an understanding that sinkholes formation in informal settlements can be a very complex and cumbersome process, and that it is activated by various human mechanisms and dynamics, it only makes sense to prepare for these hazards in a planned and orderly manner. This can be achieved through designing a risk mitigation system which is not only centred on sinkhole-resistant construction codes, with specific attention paid to unique foundation designs. Such a system should put in place special wet services designs that address:

1) the outflow of greywater from the settlements;

2) storm water management;

3) roof water discharge;

4) efficient water pipes that are not prone to bursting or leakage;

5 prohibition of the use of high amounts of water in irrigated agriculture; and

6) employment of dolomite risk management plans, and social awareness programmes.

An ongoing involvement in these programmes must be mandatory in areas identified to be at risk.

When administering risk-assessment, these awareness programmes should conduct skill-based transfer and training at household level in order to address all avenues of the affected settlements.

The decision to administer *in situ* upgrading brings with it considerable demands for accountability and responsibility pertaining to managing and mitigating the risk, in order to ensure that lives are not unduly placed at risk. This recognises the prioritisation of mitigation measures, with engineering and socioeconomic aspects at the centre of the interventions for implementation. The environmental and geological agencies, local authorities and geotechnical consultants should recognise that while the level of risk is controlled by the sinkhole size, the relevant metric size adopted is subject to change under various conditions. The recording of small ground cavities for illustration and educational needs in informal settlement is of equal importance to caution the affected communities about the probability of the development of large sinkholes in the long term and the immediate

future alike. If geotechnical investigators and geological agencies were at risk of litigation for failing to consider these micro phenomena, it is likely that equal priority would be assigned to also record the small yet impactful hazards.

The Local Municipal Dolomite Risk Managers and environmental experts, ward councillors and community leaders should strongly advise against the excavation of dumping pits for fluids and the disposal of high amounts of fresh and greywater in the pit latrines within residents' properties. A recommendation must be made to consider either contained units that are de-canted, or waterborne sanitation on dolomite. The recommendations should be administered through awareness programmes for spontaneous and voluntary participation in a shared responsibility to manage the risk.

Punitive measures should be enforced only after the interventions become ineffective or fail. It is also recommended that community leaders and residents become compliant with carrying out the much needed awareness programmes, and DRMP requirements and regulations. In addition, community leaders and residents must capacitate themselves to mitigate risk through a dolomite risk manager who is knowledgeable of what measures a DRMP should abide by, with the aim of guaranteeing sustainable developments and communities, well into perpetuity.

6.5 Future research

It is recommended that the impacts of natural factors, including weather conditions, floods, rainwater, and storm-water on the dolomitic geology of the Slovo Park informal settlement be examined.

It is also recommended that similar research be carried out in other informal communities within the City of Johannesburg to confirm if the findings are generally applicable.

More scientific research is recommended into what appears to be small cavities at two places within the settlement.

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Personal Communications

Heath, Mr. G. (18 August 2017) Engineering Geologist: Dolomite Risk Manager, Council for Geoscience.

Ntoahae, Mr. N. (27 July 2017) SPCDF Committee Leader and Slovo Park informal settlement resident.

Respondent 1 (interview, 10 August 2017) SPCDF Committee representative and Slovo Park informal settlement resident.

Respondent 2 (interview, 10 August 2017) SPCDF *Block Forum* representative and Slovo Park informal settlement resident.

Respondent 3, interview, 10 August 2017) SPCDF, *Block Forum* representative and Slovo Park informal settlement resident.

Respondent 4, interview, 11 August 2017) Slovo Park informal settlement resident.

Respondent 5, interview, 13 August 2017) SPCDF representative and Slovo Park informal settlement resident.

Respondent 6 (interview, 13 August 2017) SPCDF *Youth Forum* representative and Slovo Park informal settlement resident.

Respondent 7 (interview, 14 August 2017) Slovo Park informal settlement resident.

Respondent 8 (interview, 14 August 2017) SPCDF Committee representative and Slovo Park informal settlement resident.

Respondent 9 (interview, 14 August 2017) SPCDF *Pastors Forum* representative and Slovo Park informal settlement resident.

Appendices

Appendix I: Report displaying the dolomitic lands and available data (Source: Council for Geoscience, 2017).

OLDER NO (F)	SITE	STAND	FARM	TYPE	AUTHOR	CONSUL-TANT	REPORT NO.	SAGEOLIT	GEOREF	BORE-HOLES	OTHER	DATE	POLY-GONS	COM-MENTS	BHPLOT
435	Eldorado Park: Rand College of Education	P/ Portion 72	Olifants -vlei 316 IQ	Borehole Profiles		Ove Arup & Partners		90564138	2627BD08	7		19 June 1984	Y		Y (F2368)
435	Nancefield		Olifants - vlei 316 IR	Report		Intracon sult CC		90079301	2627BD08	38		July 1990	Y		Y (900793 02)
435	Nancefield & Bushkop-pies		Olifants -vlei 316 IR	Report		Intracon sult CC	IR28	90079302	2627BD08	38		June 1990	Y		Y
435	Olifantsvlei 316 IQ (Proposed Slovo Park)	Portion 33/R	Olifants -vlei 316 IQ	Report		Moore Spence Jones (Pty) Ltd	07-777/2	90251421	2627BD09	8		25 July 2007	Y		Y
435	Slovo Park Infill			Report		Intracon sult CC	IR1401R	90641592	2627BD08	8		April 2017	Y		Y

Appendix II – <u>Consent and Participant Information Sheet</u>

Good day,

My name is Lebea Given and I am presently enrolled at the University of Witwatersrand in the School of Architecture and Planning (SoAP) as a full-time student reading towards the Masters of Built Environment. I am conducting research on geotechnical conditions, community based practices and developments in Slovo Park informal settlement, Johannesburg, which is the title of my research.

I would hereby like to invite you to participate in this research which is part of the requirement for the fulfilment of my masters' programme, and is undertaken solely for academic purposes. You have been selected to participate in this study because you are a resident of this community, and so by being in this study you can help me better understand the social, cultural and household practices in this settlement. The research is conducted by way of interviews aimed at gathering information on social, cultural and household practices that may exacerbate sinkholes formation. Please bear in mind that this study will go a long way in steering my research in the right direction.

The interview will take a maximum duration of 20-30 minutes, and by preference the interview will take place at a time and venue of your convenience within Gauteng, particularly Slovo Park. As part of the interview, the study will inquire into what the community is doing that might lead to or induce the formation of sinkholes. I shall also ask questions relating to the handling of wet infrastructures such as water and sanitation services by the community. Lastly, the interview will delve into the awareness of the community on how sinkholes are triggered. Please note that I would like to note down the provided information and also record the interview using an audio recorder in order to get every detail of the session. However, I will only audio-record the interview if you grant me the permission to do so. The audio recordings will be subsequently transcribed for proper analysis.

The main selection criterion for participants in this study is based on involvement experience with this community and planning of the housing upgrading project. Your participation is voluntary and you may refuse to answer any question you feel uncomfortable with, you may also choose to withdraw from the study at any time without bearing any negative consequences. Participation is totally voluntary and there shall be no payment or incentive for your participation.

Your participation will be wholly anonymous, and pseudonyms such as "Respondent 1" or "Interviewee 1" will be used in the collection and analysis of the provided information. Thus, you will

not be personally identified in the final report. However, the City of Johannesburg as a government entity may be identified to give credence to the study. At any point of the study you may choose to withdraw any statement made in the interview and I will get in touch with you once I have edited the report so that you can have the opportunity to amend any omission or withdraw any information given, and also comment on the draft. Afterwards, the completed study will be available electronically, and can be accessed publicly through the University website. I would like to ensure you that all the collected data will remain confidential and I will be the only one with access to this interview data. The interview data will be reported in my Masters Research Report and Presentations.

For further information, please feel to contact me at 1246329@students.wits.ac.za or my supervisor, Prof. Aly Karam at aly.karam@wits.ac.za (011 717 7707).

If you are willing to participate in this research, please sign this form:

Signature:_____.

Date &Time: _____.

Place: _____.

Thank you for agreeing to participate in this research study.

Appendix III- Guiding Questions

The study will inquire into what the interplay is between geotechnical conditions, community practice, and developments in Slovo Park informal settlement, as part of the interview. In an attempt to answer this question, I would also ask these subsequent questions:

1) Where do you dispose of wastewater?
2) Where is the sewage discharged in the community?
3) Where do you dispose of water after washing dishes or clothes etc?
4) Do you do gardening in your yard?
    a) Do you use waste water to irrigate the garden?
    b) Do you use any pesticides that require water to be added to it?
    c) Do you use any herbicides or fertilizers in the gardens?
    d) How are the used pesticide containers disposed of?
5) Do you use a water tap to wash outside?
6) Are there any ground cavities that you use as dumpsites?
7) How do you handle burst water-pipes?
8) Do you pump water from the ground?
    a) Is there any structured management for the water-bearing system in the community?
    b) Do you abstract water from the shallow ground surface?
9) Do you know of sinkholes?
    a) How they are induced and how they form?
    b) What leads to their formation?
    c) How they can be mitigated?
10) Have there been any signs of sinkholes previously in this area, or any existing signs?
11) Is there any other information you would like to share that would be useful to my research project?

Appendix IV-Approved Ethical Clearance Certificate

SCHOOL OF ARCHITECTURE AND PLANNING
HUMAN RESERCH ETHICS COMMITTEE

CLEARANCE CERTIFICATE
PROTOCOL NUMBER: SOAP048/06/2017

PROJECT TITLE:	Geotechnical conditions, community based practices and developments in Slovo Park Informal Settlement, Johannesburg
INVESTIGATOR/S:	Given Lebea (Student no #1246329)
SCHOOL:	Architecture and Planning
DEGREE PROGRAMME:	Master of Built the Environment (MBE)
DATE CONSIDERED:	18 July 2017
EXPIRY DATE:	18 July 2018

DECISION OF THE COMMITTEE: APPROVED

CHAIRPERSON AWilliamson
(Professor Daniel Irurah) pp A.K. Williamson

DATE:

cc: Supervisor/s: Aly Karam

DECLARATION OF INVESTIGATORS

I/We fully understand the conditions under which I am/we are authorized to carry out the abovementioned research and I/we guarantee to endure compliance with these conditions. Should any departure to be contemplated from the research procedure as approved I/we undertake to resubmit the protocol to the Committee.