Mitigation of anthropogenic risk factors associated with low-cost residential development on dolomite

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ABSTRACT

The increase in growth of the South African population has for some time resulted in a progressive occupation of karst terrains. In recent case studies, evidence points to failures of precautionary measures due to gaps in awareness as well as socio-political and economic issues. These gaps negate the positive impact of science and engineering intervention on karst. Historically, karst risk was addressed on a purely technical level, but recent risk-based approaches indicate that the vulnerability of the communities living in low-cost housing in areas underlain by dolomite is exacerbated by a lack of risk awareness. If a community receives timely information regarding the management of the potential environmental disaster risk, their vulnerability to the risk can be reduced. Awareness protocols that are adapted and customised for specific scenarios and receiving environments such as low-cost housing areas are more effective in mitigating the anthropogenic risk associated with karst-related sinkhole events. These conditions include aspects such as worldview and other external factors such as socio-political context. A cluster of seven criteria were identified in mitigating the anthropogenic risk factors associated with low-cost development on dolomite: conducting a social impact assessment (SIA); the alignment of scientific knowledge with indigenous knowledge and inputs from the community; careful consideration of the political context of the community; reframing all actions and interventions by community engagement, consultation and two-way communication; multi-faceted project team reflecting community diversity and culture; respect, humility and acknowledgement of own privilege and in the final instance ethical conduct towards the community and client.

Key terms: Low-cost housing; dolomite; sinkholes; mitigation; risk communication; anthropogenic risk factors; dolomite-affected stakeholders; karst-related sinkholes; sinkhole rehabilitation; risk awareness strategy; indigenous knowledge; vulnerable communities

OPSOMMING

Die groei van die Suid-Afrikaanse bevolking lei reeds vir ’n geruime tyd tot 'n progressiewe besetting van karst-terreine. In onlangse gevallestudies dui navorsingsuitkomste op die mislukking van voorsorgmaatreëls as gevolg van leemtes in bewusmaking, sowel as sosio-politieke en ekonomiese kwessies. Hierdie gapings ontken die positiewe impak van wetenskaplike- en ingenieursintervensie tydens die besetting van karst. Histories is karstrisiko op 'n suiwer tegniese vlak aangespreek, maar onlangse risikogebaseerde benaderings dui daarop dat die kwesbaarheid van die gemeenskappe wat in laekostebehuising in dolomietgebiede woon, vererger word deur 'n gebrek aan risikobewustheid. As 'n gemeenskap tydige inligting ontvang oor die bestuur van die potensiële risiko van omgewingsrampe, kan hulle kwesbaarheid vir die risiko verminder word. Bewusmakingsprotokolle wat aangepas is vir spesifieke kontekste en ontvangsomgewings, soos laekostebehuisingsgebiede, is meer effektief tydens die mitigasie van die antropogeniese risiko wat verband hou met karst-verwante sinkgatvorming. Hierdie omstandighede sluit aspekte soos wêreldbeskouing en ander eksterne faktore soos sosio-politieke konteks in. Die uitkoms van die studie dui op ’n groepering van sewe kriteria vir die mitigasie van antropogeniese faktore in laekostebehuising areas: die uitvoer van ’n sosiale impak studie; die belyning van wetenskaplike kennis met inheemse kennis en insette van die gemeenskap; versigtige evaluering van die poltiese konteks van die gemeenskap; herraming van die aksies en intervensies deur publieke deelname, konsultasie en tweerigting kommmunikasie; projekspan met verskeidenheid van fasette wat die diversiteit en kultuur van die gemeenskap reflekteer; respek en nederigheid en erkenning van bevoorregting en eindelik ook die etiese optrede teenoor die gemeenskap en kliënt.

Sleutelterme: Laekostebehuising; dolomiet; sinkgate; mitigasie; dolomietrisikobewusmaking; antropogeniese faktore; dolomietgeaffekteerde belanghebbendes; dolomietverwante sinkgate; dolomietrisikobewusmakingstrategie; inheemse kennis, dolomietgeaffekteerde kwesbare gemeenskappe

ABSTRACT: SETSWANA

Palo e kwa godimo ya kgolo ya baagi ba Aforika Borwa e supa tswellopele ya tiragalo ya magaga. Dipatlisiso tse di ntšhwa di bontsha gore megato ya ditlhokomediso mo baaging, tsamaisong le tsa moruo e ya fokola. Go fokola ga megato ya go tlhokomedisa baagi go dira gore mosebetsi o mogolo o setseng o dirilwe ke ditsibi go fokotsa maemo a kotsi o sa bonagala. Bogologolo kotsi e ene e tlhatlhobiwa ke bo ra setegeniki, fela dipatlisiso tsa segompieno tse mekamekanang le dikotsi di bontsha gore batho ba ba dulang matlong a tlhwatlhwa e kwa tlase moo go nang le letlapa la dolomite, ba ka tlase ga kotsi e tlholwang ke go tlhoka kitso ka kotsi e ba leng mo go yona. Fa baagi ba bona kitso ka bonako ka kotsi e ba leng mo go yona ka lebaka la tikologo eo ba leng mo go yona, bogolo ba kotsi bo a fokotsega.Tlhokomediso e diretsweng maemo le tulo e riling, ja ka batho ba dulang matlong a theko e tlase e dira phaphang e golo go fokotsa kotsi e dirwang ke mesima ya tlhaho. Maemo ana a kenyelletsa dikarolo tse kang pono ea lehatse le dintla tse ding tse kang tsa sechaba, polotiki le tsamaiso sechabeng.

Mantswe a bohlokoa: Matlo a theko e tlase; Lejwe la dolomite; mesima; puisano ka kotsi; mabaka a etsang hore tikoloho e be kotsing; bankakarolo ba angweng ke dolomite; mesima a bakwang ke mahaha; tukiso ya mesima; tsela ya ho tsibisa ka kotsi; tsebo yak gale; Sechaba se kotsing.

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LIST OF ABBREVIATIONS

AGES	Africa Geo-environmental Engineering & Science
ALARP	As Low as Reasonably Practicable
BNG	Breaking New Ground
CGS	Council for Geoscience
DLO	Drilling Liaison Officer
DMD	Dolomite Management Desk
DMV	Disaster Management Volunteers
DRCS	Dolomite Risk Communication
DRCS	Dolomite Risk Communication Strategy
DRMA	Dolomite Risk Management Area
DRMPr	Dolomite Risk Management Programme
DRMS	Dolomite Risk Management Strategy
DRMP	Dolomite Risk Management Plan
DSC	Dolomite Steering Committee
DSI	Dolomite Stability Investigation
GIS	Geographic Information System
IDP	Integrated Development Plan
IRAF	Integrative Research and Awareness Framework
MLM	Merafong Local Municipality
MM	Municipal Manager
NGO	Non-Governmental Organisation
NHBRC	National Home Builders Registration Council
RAP	Resettlement Action Plan
RDP	Reconstruction and Development Plan
SAF	Social Awareness Framework
SALGA	South African Local Government Association
SANS	South African National Standards
SC	Steering Committee
SIA	Social Impact Assessment
TCC	Tlokwe City Council
UK	United Kingdom
UN	United Nations
UNISDR (UNDRR)	United Nations office for Disaster Risk Reduction
USA	United States of America
wad	weathered after dolomite
WC	Ward Councillor
ZAR	Zuid Afrikaansche Republiek

LIST OF CHEMICAL COMPOUNDS

Ca	Calcium
Cl	Chloride
CO_2	Carbon Dioxide
CO_3	Carbonate
Cu	Copper
F	Fluoride
Fe	Iron
H_2O	Water
HCO_3	Bicarbonate
K	Potassium
N	Nitrogen
Na	Sodium
Mg	Magnesium
Mn	Manganese
pH	Measure of acidity / alkalinity
SO_4	Sulphate
Zn	Zinc

Terminology

Hazard: “A potentially damaging physical event, phenomenon or human activity that may cause the loss of life or injury, property damage, social and economic disruption or environmental degradation…Each hazard is characterised by its location, intensity, frequency and probability”

Vulnerability: “The conditions determined by physical, social, economic, and environmental factors or processes, which increase the susceptibility of a community to the impact of hazards.”

Risk: “The probability of harmful consequences, or expected losses (deaths, injuries, property, livelihoods, economic activity disrupted or environment damaged) resulting from interactions between natural or human-induced hazards and vulnerable conditions.”

Risk Assessment or Analysis: “A methodology to determine the nature and extent of risk by analysing potential hazards and evaluating existing conditions of vulnerability that could pose a potential threat or harm to people, property, livelihoods and the environment on which they depend.”

Capacity or Capability: “A combination of all the strengths and resources available within a community, society or organization that can reduce the level of risk, or the effects of a disaster.”

Coping capacity: “The means by which people or organizations use available resources and abilities to face adverse consequences that could lead to a disaster.”

Resilience: “The capacity of a system, community or society potentially exposed to hazards to adapt, by resisting or changing in order to reach and maintain an acceptable

level of functioning and structure. This is determined by the degree to which the social system is capable of organizing itself to increase its capacity for learning from past disasters for better future protection and to improve risk reduction measures.”

Disaster: “A serious disruption of the functioning of a community or a society causing widespread human, material, economic or environmental losses which exceed the ability of the affected community or society to cope using its own resources.”

Disaster Risk Management: “The systematic process of using administrative decisions, organization, operational skills and capacities to implement policies, strategies and coping capacities of the society and communities to lessen the impacts of natural hazards and related environmental and technological disasters. This comprises all forms of activities, including

structural and non-structural measures to avoid (prevention) or to limit (mitigation and preparedness) adverse effects of hazards."

Disaster Risk Reduction: "The conceptual framework of elements considered with the possibilities to minimize vulnerabilities and disaster risks throughout a society, to avoid (prevention) or to limit (mitigation and preparedness) the adverse impacts of hazards, within the broad context of sustainable development."

Prevention: "Activities to provide outright avoidance of the adverse impact of hazards and means to minimize related environmental, technological and biological disasters."

Mitigation: "Structural and non-structural measures undertaken to limit the adverse impact of natural hazards, environmental degradation and technological hazards."

Preparedness: "Activities and measures taken in advance to ensure effective response to the impact of hazards, including the issuance of timely and effective early warnings and the temporary evacuation of people and property from threatened locations."

Early warning: "The provision of timely and effective information, through identified institutions, that allows individuals exposed to a hazard to take action to avoid or reduce their risk and prepare for effective response."

According to these definitions, a sinkhole forming would be seen as a **hazard**. The conditions that determine the community's susceptibility to be affected by the hazard, are defined as the **vulnerability**. The probability of harmful consequences or expected losses from a potential sinkhole is seen as the **risk**. Generally, risk is expressed as a function of hazard and vulnerability as follows (United Nations, 2004):

Risk = Hazard x Vulnerability

By implication nuclear power stations and coastal residents on the east coast of Japan would be more vulnerable to a Pacific tsunami hazard than infrastructure or people living farther inland, and therefore at greater risk. Similarly, communities residing on cavernous dolomite are more vulnerable to sinkholes forming than communities on i.e. shale or sandstone. Analysing the potential hazards of sinkholes forming (hazard assessment), and evaluating the conditions pertaining to the vulnerability of communities (vulnerability assessment) therefore would form the basis of risk assessment.

CHAPTER 1: LIVING ON DOLOMITE

1.1 Introduction

Over the past two centuries the world population has increased exponentially, reaching over 7.8 billion people in 2020 (Gutiérrez *et al.*, 2014:62). By 2050 the world population is projected to reach 9.7 billion people (Worldpopulationreview, 2020). The United Nations Population Fund (United Nations, 2019) projected that the population of sub-Saharan Africa will have contributed to 52% of the United Nations projection for the world population in 2050. This ever-increasing number of people has resulted in accelerated urban expansion, densification, and increasing occupation of land. It is also projected that by 2030, 71.3% of South Africa's population will live in urban areas (Gardner & Graham, 2018:27). In the South African context, this would also include land not earmarked for development or without the necessary infrastructure to accommodate settlements. Of even greater concern is the occupation of karst[1] terrains, specifically dolomitic areas.

There are environments that are more fragile than others and therefore more vulnerable than others, depending on a series of factors such as geology, geomorphology, hydrogeology and humans living on or close to them. Karst, with its very direct relationship between surface and subsurface geological elements such as morphology and hydrology, is one of the most vulnerable of these environments (Gutiérrez *et al.*, 2014:62).

Karst terrains form through weathering processes over millions of years. It typically forms cavities and cave systems (Department of Water Affairs and Forestry, 2006:3). The Department of Public Works (2010:5) explain that: *"*Rainwater and percolating ground water gradually dissolve the rock over time as it seeps through joints, fractures and fault zones in the rock*"*. These sedimentary rocks are further classified into two broad classes, namely carbonate and evaporite rocks. Dolomite is identified as a carbonate rock (Stevanović, 2015:25). The increase in population and resource demand is accompanied by a progressive occupation of karst terrains. In order to minimise the effects of human settlement and the hazards inherent to these vulnerable and complex areas, residents living on karst will have to learn how to live with karst (Gutiérrez *et al.*, 2014:62).

This karst landscape can be buried under younger deposits or weathered deposits of karst formation, which can collapse or move into the cavities, resulting in ground movement (Buttrick *et al.*, 2001:27). When structures are built on karst, the possibility of sinkholes forming increases

[1] Karst as term is used interchangeably with the term dolomite, as karst also includes dolomitic landscapes.

substantially. Sinkholes are ground collapses that occur as a consequence of the synergy between predisposing and triggering mechanisms (Intrieri *et al.*, 2018:1). These mechanisms are delineated in Chapter 3, which defines the risk posed by dolomite in the low-cost built environment.

In South Africa, 38 people have died in sinkholes that have occurred under sports clubs, factories and homes, and associated financial losses have exceeded R1 billion. More than 1000 sinkholes have occurred on the West Rand, 800m south of Pretoria, Centurion and Atteridgeville, and approximately 150 on the East Rand (Department of Public Works, 2010:6). In Ikageng, Promosa and Mohadin in the North West province of South Africa, various sinkholes have formed over the past few years with great associated risk to residents and to the JB Marks Municipality[2]. Communities in affected areas have been relocated at a cost of more than R10 000 million[3] (Buttrick *et al.*, 2011b; Kleinhans & Van Rooy, 2016:3).

The South African National Standards (SANS) 1936-4 (2012) regulate any development on dolomite in South Africa. It prescribes that the local authority of areas underlain by dolomite must establish and implement a dolomite risk management programme (DRMPr). A DRMPr consists of a dolomite risk management strategy (DRMS) and dolomite risk management plan (DRMP).

The Tlokwe City Council (TCC) appointed a consultancy to develop a DRMPr to manage and mitigate the risk related to dolomite within its jurisdiction (Council Resolution C122/2012-06-19; MM Resolution 75/2009-05-09; Council Resolution C120/2010-06-09; Council Resolution 244/2011-11-29; MM Resolution 163/2011-11-24). As part of this programme, a dolomite risk communication strategy (DRCS) was also developed to create awareness, communicate risk and to equip all residents. Part of the problem that this thesis addresses is whether these actions have been effective in communicating the reality of the risks to the most vulnerable residents residing on dangerous dolomite.

Dwyer *et al.* (2004:12) explain that vulnerability refers to different people or groups' capacity to cope, resist and recover from a disaster or adverse condition. The vulnerability of communities living in low-cost housing underlain by karst can be reduced by communicating effectively about all risks in such a way that the community takes ownership of managing and mitigating the risk.

Development on karstic rocks may be affected by natural subsidence, but the karst itself can be affected by subsidences induced by anthropogenic factors such as inappropriate drainage. It is

[2] The case study and documentation used for this thesis were developed during a period when the municipality was still known as Tlokwe City Council. For the remainder of this thesis it is thus referred to as TCC.

[3] US $600 million.

well-documented that the redirection of storm run-off may lead to sinkhole development and pollution of karstic aquifers (Fleury, 2009:28). This is a major constraint that must be considered in many sinkhole-prone areas. However, as Fleury (2009:83) points out, many counties and states in the USA – even adjacent ones – have very different regulations, and as for the USA, there is no definitive consensus on what is required to mitigate anthropogenic risk or manage dolomite in general.

There are two primary factors contributing to the risk of low-cost development on karst that should be addressed during planning. The first includes all aspects of the physical environment, such as geology, geohydrology and engineering geology (Potgieter, 2012:35). According to Tihansky (1999:1), this scientific understanding is key to assigning meaningful risk to both property and environment and thereby formulating effective land and water resource management strategies. The second factor relates to the anthropogenic environment, which points to existing infrastructure development, land use planning and the social structure within the study area (Potgieter, 2012:35). The focus on anthropogenic factors is acknowledged by means of specifications in the SANS (2012a) pertaining to the inclusion of an awareness programme.

Buttrick *et al.* (2014:131) point to recent failures of precautionary measures due to gaps in awareness, training, and socio-economic challenges. Buttrick *et al.* (2014:131) also indicate that these gaps negate the positive impact of science and engineering intervention on karst. Historically, karst risk was addressed at a purely technical level, but recent risk-based approaches indicate that the vulnerability of the community is exacerbated by insufficient risk awareness (Buttrick *et al.*, 2014:131; Muller, 2017:2).

If a community receives timely information regarding the management of the potential environmental disaster risk, their vulnerability to the risk might be reduced. Wisner *et al.* (2012:12) describe an environmental disaster risk as a “function of the magnitude, potential occurrence, frequency, speed of onset and spatial extent of a potentially harmful event or process. It is also a function of people’s susceptibility to loss, injury or death.” An environmental disaster risk therefore refers to a potentially harmful event that may cause great loss in terms of property and human life.

In a documentary produced by Channel 5 (2017), in the United Kingdom (UK) , residents express their distress at sinkholes having fallen in Ripon in the United Kingdom. They were unaware of the possibility of impending disaster and they are now left unsure of what the future holds. Homes have been left abandoned and the town’s long-awaited swimming pool might not materialise due to ground collapse. On the other side of the globe, residents living in Ikageng in the North West province of South Africa share their distress and uncertainty. Sinkholes are forming, residents are

being resettled, and any plans for development and extension of homes hang in the balance. In some cases, rehabilitation of karst-related surface instabilities has been delayed for years. Numerous risk awareness attempts have been made as part of mitigation, yet communities feel unsure and live in fear (Tlokwe City Council, 2011a; Tlokwe City Council, 2011b; Tlokwe City Council, 2012; Tlokwe City Council, 2013; Tlokwe City Council, 2014a; Tlokwe City Council, 2014b; Muller, 2017).

As a scientist it is encouraging for me to see an interdisciplinary project such as the TCC DRMS develop through the project life cycle with an extensive public participation and risk communication campaign. It is gratifying to experience residents' response to the different channels and agencies through which the awareness campaign was implemented. When following such a high intensity and prolonged campaign, it is disheartening when residents suddenly refuse to move from perilous sinkhole sites, decline to receive awareness material, and refute the existence of dolomite. How do you mitigate anthropogenic factors to ensure the safety of residents living in low-cost developments if it seems as if the stakeholders are all responding in a way contrary to what you have come to expect?

This study takes a step back in order to move forward. In the research that the study at hand uses as baseline (Muller, 2017), a conceptual framework is proposed for the compilation of dolomite risk awareness strategies for the mitigation of anthropogenic risks. The need for guiding criteria to inform the nuanced implementation of this framework is obvious and this is highlighted by the research reported in this thesis.

The step back is to look closely at the hazards presented by dolomitic ground and the mechanisms that govern sinkhole formation. This also entails that the anthropogenic factors that can and should be mitigated are analysed to isolate the critical information that should be communicated to stakeholders. Secondly, the nature and impact of low-income housing in dolomitic areas are evaluated in terms of the relevant anthropogenic factors that should be mitigated. The case study presented in this research is analysed along with the response of the affected community to the mitigation interventions employed.

The study area covers various low-cost housing areas in Ikageng, North West province, South Africa, with reference to relevant case studies locally and globally. The study area was chosen due to the involvement it the TCC DRMS and the evidence as presented in Muller (2017) which supported the evidence that the TCC case study is the only DRMS with robust and complete mitigation strategies and implementation of these risk reduction strategies in low-cost housing areas. Will the implemented awareness actions provide relevant criteria that can enhance mitigation? Or, will awareness protocols that are adapted and customised for scenarios and

receiving environments such as low-cost housing areas be more effective in mitigating the anthropogenic risk associated with karst-related sinkhole events? These conditions may include aspects such as worldview and other external factors.

This thesis then aims to establish criteria for creating risk awareness. The study also makes recommendations to stakeholders affected by karst-related sinkholes in low-cost housing areas on how to mitigate for anthropogenic risk, thereby reducing the overall risk to vulnerable communities.

1.2 General and specific research questions

1.2.1 General research question:

How can the mitigation of anthropogenic risk factors be enhanced by the customisation of risk awareness actions in communities living in low-cost housing with dolomite-related surface instabilities, with specific reference to Ikageng, South Africa?

1.2.2 Specific research questions

1. To which anthropogenic hazards associated with dolomite-related sinkholes as presented in the case study are the affected communities living in low-cost housing exposed?

2. What risk awareness measures have the local authorities in the presented case study put in place to mitigate the anthropogenic risk to communities living in low-cost housing areas with dolomite-related sinkholes?

3. How have the affected communities in the presented case studies responded to the mitigation measures and awareness actions initiated by the local authorities?

4. Which are the critical factors that influence the effectiveness of risk awareness actions in areas with low-cost housing to mitigate anthropogenic factors in dolomite-related sinkholes?

5. What are the criteria that can be used to implement more effective risk awareness actions in communities living in low-cost housing areas and affected by dolomite-related sinkholes?

1.3 Chapter guideline

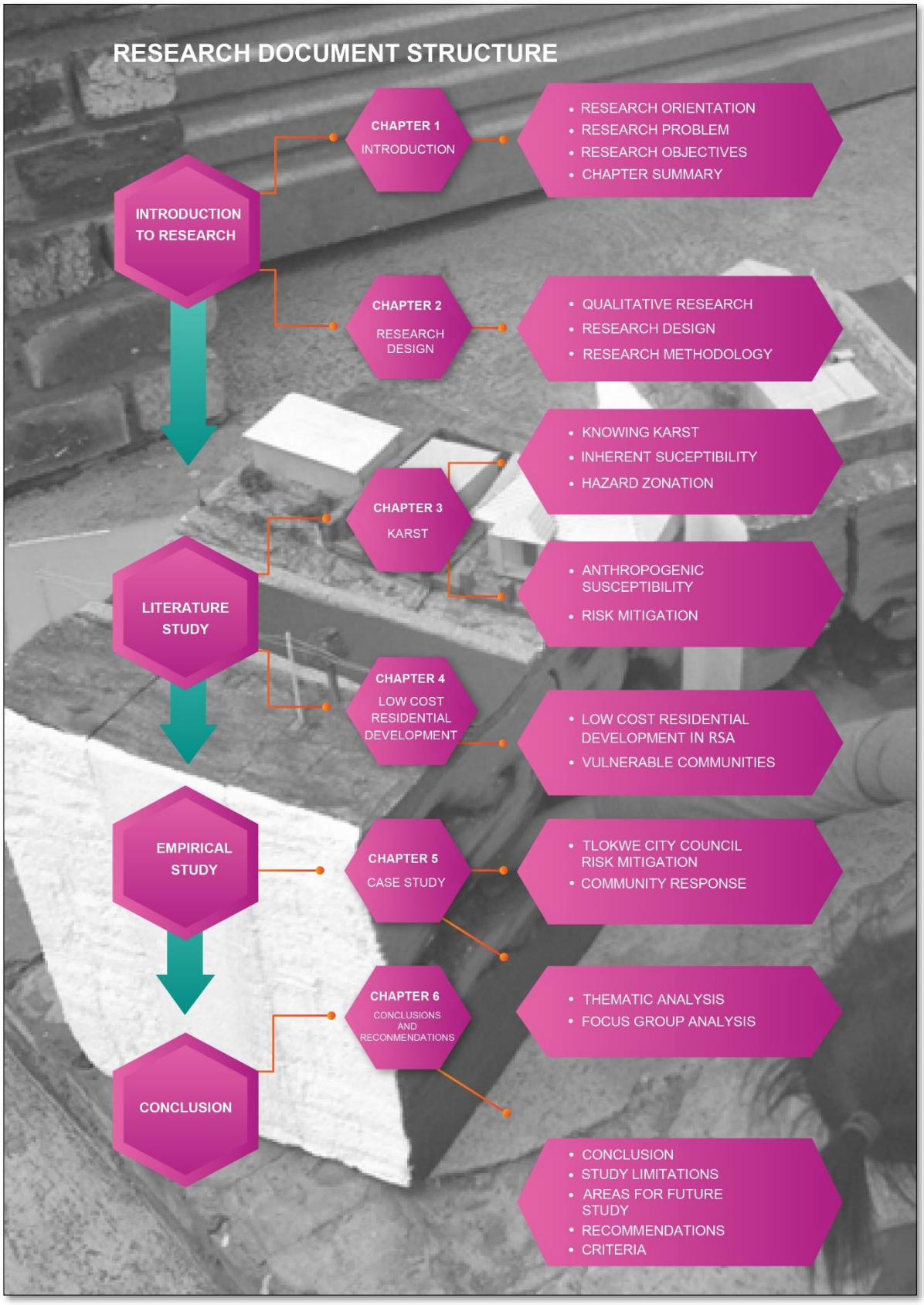


Figure 1-1: Research document chapter guideline

1.4 Overview

Chapter 1 defined the problem and stated the research questions, while chapter 2 describes the research design and methodology, theoretical and conceptual framework, literature review and the description of the empirical research. In Chapters 3 and 4 the two coinciding risks namely dolomite and low-cost housing is discussed and the anthropogenic risk this leads to. Chapter 5describes the context of the case study and the dolomite risks awareness actions and the responses of the community to these interventions as well as the gaps in awareness and the focus group discussion that forms the basis of the thematic analysis and coding which leads to the isolation of prevalent themes. In chapter 6 the main categories resulting from the study are discussed and criteria formulated accompanied by recommendations including options for further study.

Dolomite and other karst landscapes pose inherent risks to communities who have built dwellings on it. This risk is amplified when the communities are living in low-cost developments and are themselves vulnerable and not equipped to make informed decisions regarding their own mitigation of anthropogenic risk factors or mitigation on the side of local government. The research methodology implemented in an attempt to respond to the research questions in this study, are described in the following chapter (Ch. 2).

CHAPTER 2: RESEARCH METHODOLOGY

2.1 Introduction

Chapter 1 offers some background to and motivation for the research reported in this thesis. Section 1.2 has presented the research problem and research question. In this chapter the research actions used to respond to these questions and address the research problem are described and motivated. Questions emanate from our perspective and our experience of uncertainty and reservations concerning something that has occurred, defining our doubt and current interpretations (Charmaz, 2017:34). The questions in this thesis are addressed with the ontological assumption that the outcomes of the research can offer multiple versions and perceptions of reality (Creswell & Poth, 2018:20). The study takes an interpretivist epistemological stance linking facts and values as acceptable expressions of scientific knowledge. This philosophy underpins the choice of a qualitative research approach.

2.2 Emergent constructivist grounded theory

Qualitative research aims to pursue understanding and describe in a narrative way how people view and experience life and the world around them. It also aims to identify, analyse and study themes and patterns from collected data. The significance and importance of these patterns are determined by the research question (Malhotra, 2008:170). Qualitative research is also flexible and can be adapted by the researcher as the study progresses (Babbie & Mouton, 2002:80; Malhotra, 2008:79-81).

In qualitative research, the people's viewpoints and experiences are entrenched in the context in which they live, and the way they attach meaning to it may change over time and is mostly subjective (Ravitch & Carl, 2019:9). It is therefore ideally suited to study the mitigation of anthropogenic factors in low-cost housing on dolomite. The perceptions and response of communities to dolomite and anthropogenic factors have a profound influence on effective mitigation.

Applying emergent constructivist grounded theory, the findings are presented as a narrative of theory and empirical application in the field. As a qualitative methodology, this method facilitates theory where no sufficient or applicable theory exists to use as foundation for research. This version of grounded theory is based on the work of Charmaz (2008; 2017). Other versions of grounded theory do not identify the outcome in terms of a research process in historical, social and contextual terms (Charmaz, 2017:34). Emergent research identifies and studies themes that emerge from data but is not solely guided by research questions. Emergent research starts with

the empirical world (Charmaz, 2008:155), and in this instance studies aspects of a phenomenon (dolomite) where there is a gap in theory. The gap in theory as indicated in Table 2.1 encompasses the areas of risk communication on low-cost housing areas on dolomite and DRMS awareness actions and implementation of measures to mitigate anthropogenic risk in general. Methodologies can subsequently be implemented in the empirical setting and the outcomes of this in turn inform the aspects of theory that should be researched. The case study presented follows this pattern and employs grounded theory to do so.

It is evident that the roots of this research are in grounded theory as it is based on systematic and varied methods of collecting and analysing data. Emergent aspects are isolated through deductive, abductive and hypothetical reasoning, explicitness, flexibility and systemic analysis (Charmaz, 2008:155). The advantage of grounded theory is that analysis and categorisation is emphasised rather than results (Charmaz, 2008).

Researching a community as their lives intersect with a natural hazard that places them and their earthly possessions at risk daily, over many years, naturally leads to immersion in research data and theoretic analysis. Constructivist researchers view themselves as embedded in the process and not outside of it. It should be the same for the method applied. The method must reside within the research (Charmaz, 2008:160). By reflectively presenting our data, methodology, approach and own stance to rigorous scrutiny can influence the way we see our research and our role in it. Through this reflexive stance, our worldviews, and in some cases unearned or unaware privilege, are uncovered (Charmaz, 2017:34). The weakness of using this method is that the researcher has to work with masses of data which may prove difficult to handle and use correctly. There is also no standard rules for coding and the researcher has to develop own standards procedures for coding which can be very subjective. Grounded theory is therefore more suited to experienced researchers.

As constructivist grounded theorists begin researching and engaging with their data, their viewpoints may evolve and therefore they may allow for structure and content to be emergent. This means they may design and adapt methodological strategies to what emerges throughout the study (Charmaz, 2017:35). Grounded theory has become more of a range of methods than just one conventional approach.

Critical qualitative inquiry as an interpretive framework locates discourses of injustice, inequality and power and ways to redress it (Charmaz, 2017:35). It is underpinned by a transformative paradigm that in the application of Charmaz's (2008; 2017) method, moves the discourse to the dilemma of disadvantaged people. I would in the light of this study and personal preference prefer the term vulnerable above disadvantaged, although even this term may not be descriptive of the

total category studied. Typically, research methods used in qualitative research are ontologically and epistemologically individualistic (Charmaz, 2017:36). Therefore, the reflexive stance and iterative nature of constructivist grounded theory is well suited to the multi-cultural community context.

2.3 Literature study

The objective of the literature overview is to identify the most important literature in the field of anthropogenic risk mitigation on karst-related[4] sinkholes, and to investigate the characteristics of low-cost housing that renders the dwellings and their inhabitants vulnerable and at risk on dolomitic ground. It also emphasises the risk awareness practices implemented in the case study researched in this thesis.

After defining the risk posed by karst-related sinkholes, the focal point of the documented case study is to investigate the response of vulnerable communities in low-cost housing areas to the risk they are exposed to and the way in which they have responded to awareness measures to reduce the risk and enhance anthropogenic risk mitigation.

The following databases were consulted: Ferdinand Postma library catalogue, SACat, EBSCOhost: Academic Search Premier; Business Source Premier; Communication & Mass Media Complete; EconLit; MCB Emerald; Jstor; Sage Publications; NEXUS; ScienceDirect; SA ePublications; Internet search engines. It has been determined that enough information is available to complete this study.

The literature search indicated a gap in research and literature on karst-related sinkhole risk awareness globally, as well as the mitigation of anthropogenic risk factors for low-cost housing on dolomite by means of awareness actions and protocols.

Although this field intersects with disaster management, the main foci is the intersection of scientific knowledge on the mitigation of anthropogenic factors with vulnerable communities in the context of risk communication. There are many studies that have researched the management of disasters. We know that dolomite is an impending and sometimes imminent disaster and that awareness mitigates or reduces this risk. This thesis adjusts the focus to zoom in on a specific scenario within the bigger framework of disaster risk reduction. The following definition of disaster

[4] The terms karst and dolomite are used interchangeably. Karst is the overarching term, while dolomite is one of the manifestations of karst.

risk reduction suffices for the purpose of this study:

Disaster risk reduction is aimed at preventing new and reducing existing disaster risk and at managing residual risk by providing a framework of elements that would contribute to strengthening resilience and minimising the impact of the hazard to assist with the achievement of sustainable development (UNISDR, 2009; Kelman, 2018:3).

The multi-disciplinary positioning of this thesis means that not all issues applicable could be investigated, but that the literature study had to be limited to issues that directly affect the core of the research problem. Key terminology are defined as they are introduced as concepts in the study.

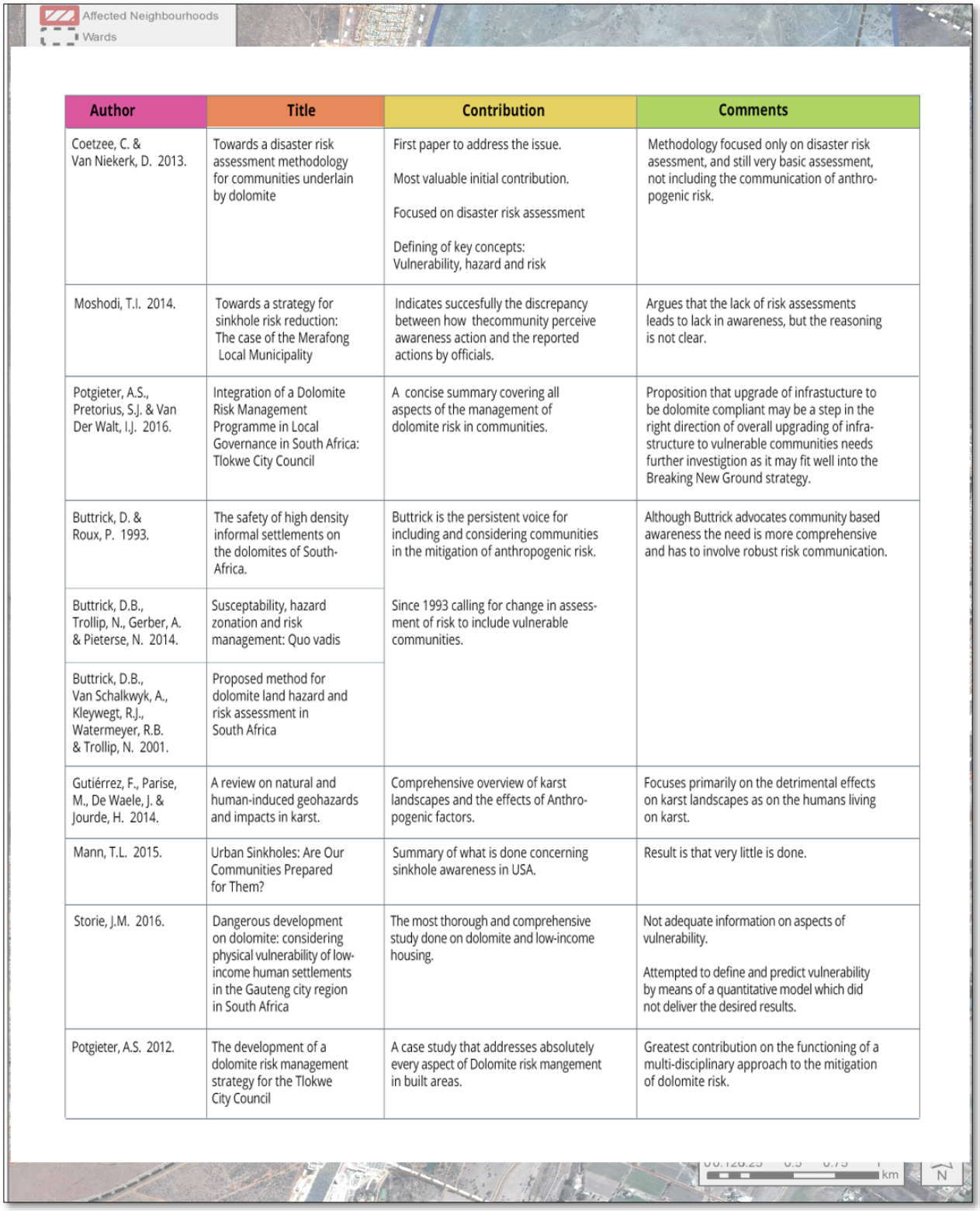
The theoretical framework in Figure 2.1 illustrates the multi-disciplinary nature of this thesis:



Figure 2-1: Theoretical framework

The literature study highlights the dichotomy in this field of study. Traditionally, the study of karst and its anthropogenic factors and low-cost housing as variable is presented as positivist technical material. This is still the case today. In investigating karst and sinkholes as phenomenon, it is the only acceptable practice. The reality of the coincidence of karst and communities, especially vulnerable communities, creates not only an amplifying anthropogenic effect, but places people at great risk. Excluding these factors from case studies would mean that one would never fully account for the successful mitigation of risk. Table 2.1 offers a summary of the authors who have adequately addressed anthropogenic mitigation in terms of communities living on karst. In Chapter 5, the different contributions are also accentuated as the respective themes and interventions are introduced.

Table 2-1: Literature summary (Original contribution)



Author	Title	Contribution	Comments
Coetzee, C. & Van Niekerk, D. 2013.	Towards a disaster risk assessment methodology for communities underlain by dolomite	First paper to address the issue. Most valuable initial contribution. Focused on disaster risk assessment Defining of key concepts: Vulnerability, hazard and risk	Methodology focused only on disaster risk assesment, and still very basic assessment, not including the communication of anthropogenic risk.
Moshodi, T.I. 2014.	Towards a strategy for sinkhole risk reduction: The case of the Merafong Local Municipality	Indicates succesfully the discrepancy between how thecommunity perceive awareness action and the reported actions by officials.	Argues that the lack of risk assessments leads to lack in awareness, but the reasoning is not clear.
Potgieter, A.S., Pretorius, S.J. & Van Der Walt, I.J. 2016.	Integration of a Dolomite Risk Management Programme in Local Governance in South Africa: Tlokwe City Council	A concise summary covering all aspects of the management of dolomite risk in communities.	Proposition that upgrade of infrastucture to be dolomite compliant may be a step in the right direction of overall upgrading of infrastructure to vulnerable communities needs further investigtion as it may fit well into the Breaking New Ground strategy.
Buttrick, D. & Roux, P. 1993.	The safety of high density informal settlements on the dolomites of South-Africa.	Buttrick is the persistent voice for including and considering communities in the mitigation of anthropogenic risk. Since 1993 calling for change in assessment of risk to include vulnerable communities.	Although Buttrick advocates community based awareness the need is more comprehensive and has to involve robust risk communication.
Buttrick, D.B., Trollip, N., Gerber, A. & Pieterse, N. 2014.	Susceptability, hazard zonation and risk management: Quo vadis		
Buttrick, D.B., Van Schalkwyk, A., Kleywegt, R.J., Watermeyer, R.B. & Trollip, N. 2001.	Proposed method for dolomite land hazard and risk assessment in South Africa		
Gutiérrez, F., Parise, M., De Waele, J. & Jourde, H. 2014.	A review on natural and human-induced geohazards and impacts in karst.	Comprehensive overview of karst landscapes and the effects of Anthropogenic factors.	Focuses primarily on the detrimental effects on karst landscapes as on the humans living on karst.
Mann, T.L. 2015.	Urban Sinkholes: Are Our Communities Prepared for Them?	Summary of what is done concerning sinkhole awareness in USA.	Result is that very little is done.
Storie, J.M. 2016.	Dangerous development on dolomite: considering physical vulnerability of low-income human settlements in the Gauteng city region in South Africa	The most thorough and comprehensive study done on dolomite and low-income housing.	Not adequate information on aspects of vulnerability. Attempted to define and predict vulnerability by means of a quantitative model which did not deliver the desired results.
Potgieter, A.S. 2012.	The development of a dolomite risk management strategy for the Tlokwe City Council	A case study that addresses absolutely every aspect of Dolomite risk mangement in built areas.	Greatest contribution on the functioning of a multi-disciplinary approach to the mitigation of dolomite risk.

2.4 Empirical study

2.4.1 Context

The case study research that was completed as part of a previous study (Muller, 2017), was done while working as a consultant for a geotechnical and environmental firm[5]. While the project was overseen by an interdisciplinary team, the risk mitigation interventions were developed and applied and overseen by me. This being said, the extremely valuable role and input of all team members and an experienced external consultant[6] cannot be overstated. The second phase research as presented in this thesis was completed while no longer working as consultant and is based on secondary data. I conducted the focus group discussion concurrently with the conclusion of the DRMPr, but it was not analysed for thematic content and was not theorised before writing up this thesis.

2.4.2 Data collection analysis and interpretation

The use of an emergent method signifies that there may be unexpected outcomes that may be pursued (Charmaz, 2008:157). The unexpected reaction of the community in response to the mitigation interventions in the first stage of the TCC study as represented here, which will be described in more detail in Chapter 5, prompted the research questions postulated in this thesis. Grounded theory begins with inductive reasoning, but as an anomaly occurs it uses abductive reasoning, which elicits creative interpretations based on theoretical possibilities. These options are then tested against the hypothesis until one arrives at the most feasible interpretation of the data available (Charmaz, 2008:157). Progressively more categories are established as the successive layers of empirical research are surveyed. Not only do the data in the setting reveal itself, but the researchers experience, ideas and field of expertise may provide a more inclusive approach to the interpretation of data (Corbin & Strauss, 2014:13).

The iterative structure of grounded theory alternating between collection of data, analysis and theorising elevates the emergent levels of analysis (Charmaz, 2008:161). In this thesis, the iterative structure is visible in the revisiting of the previous case study research to isolate early themes and semantic categories that led to interventions. The theory in which these themes was grounded is also highlighted.

Due to the extreme politicising of the dolomite, the decision was made to conduct a focus group

[5] Africa Geo-Environmental Engineering and Science (Pty.) Ltd.

[6] Dr Ilse Aucamp from Equispectives Research and Consulting Services

discussion in order to reflect on the previous mitigation and to prepare for a strategy going forward. Sampling from the affected residents had the potential to ignite a spark and turn unwanted attention to the issue. The focus group comprised spiritual leaders representing the high-risk dolomitic areas with low-cost housing structures.

The focus group was conducted as a semi-structured discussion to facilitate the flow of the conversation. The transcript of this focus group was used to identify these semantic categories.

This type of thematic analysis was chosen to identify salient themes that could be identified from the concepts, narratives and insights of the participants.

In the final phase the focus group transcript, which was the final action of the research before the project was concluded, was subjected to content analysis. Section 2.4.3 describes this process. The core categories were subsequently applied to project information, from where the emergent categories were theorised and the combined prime categories identified in order to set criteria for the mitigation of anthropogenic factors in low-cost housing on dolomite.

2.4.3 Content analysis

Data coding was conducted to analyse the content of the focus group discussion, using Computer-Assisted Qualitative Data Analysis Software (CAQDAS), more specifically ATLAS. ti. version 8. The “constant comparative analysis” of grounded theory is well suited to uncover patterns across documents. This software does not assist in isolating themes but rather connects themes across content and documents.

2.4.3.1 Open coding

When using grounded theory, researchers code while collecting data, scrutinising data for analytic potential. This is the first step of categorising. The mass data accumulated during the research process were scanned for obvious categories.

2.4.3.2 In vivo coding

The next level of coding is *in vivo* coding. This coding cycle uses the transcript of the focus group discussion. When coding this way, the direct words or phrases of the participants are used as codes. This coding helps to organise, synthesise and categorise into interpretive concepts. This first cycle coding is generic, while the second cycle coding is more conceptual.

2.4.3.3 Axial coding

Axial coding connects these codes in relation to one another by trying to elicit connections. The next step is to do selective coding where the core variable is isolated and other data are then coded in relation to the identified core variable.

2.4.3.4 Selective coding

The case study and all the identified supporting data such as memos, minutes of meetings, reports, door-to-door registers, workshops, liaisons, media articles and enquiries were explored to identify recurrence of the core variables and possible new axial relationships.

As already described, the method employed allows the researcher to return to the coding map to add emergent codes and core variables that are evident in the supporting documents. Core salient categories were well populated after this last step was completed. The categories can then be analysed and theorised. Figure 2-2 illustrates the framework of concepts that serve as foundation for this thesis and from which broad categories will be generated.

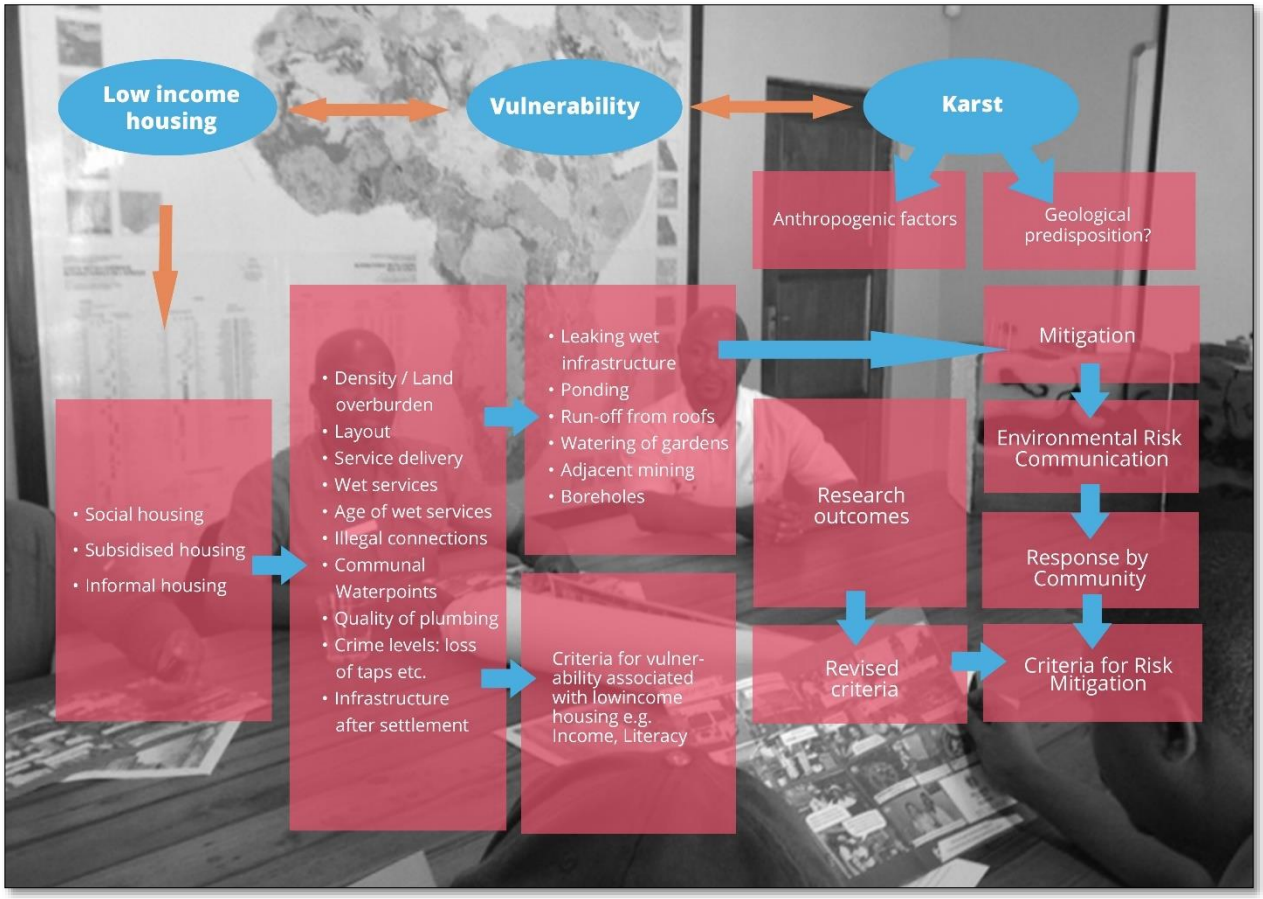


Figure 2-2: Conceptual framework (Original contribution)

2.4.3.5 Data representation

Outcomes of the coding are represented in the form of Atlas.ti generated code maps and tabled summaries of the findings.

The emerging new theoretical constructs were aligned to existing or emergent theories in order to formulate relevant criteria in response to the research problem.

2.5 Research outcomes

The combined findings of the literature and empirical study are presented in Chapters 5 and 6 of this thesis. New criteria for effective mitigation of anthropogenic factors in low-cost housing areas on dolomite are proposed.



Figure 2-3: Research components (Original contribution)

2.6 Ethical considerations

The research study adhered to the ethical considerations associated with project implementation. In reporting the outcomes of the research, the anonymity of project participants was ensured. The

views of all stakeholder groupings were considered respectfully and reported objectively and with empathy within the contextual framework.

All data are secondary and all documents from TCC and consultants were examined in respect to the availability of the data in the public domain.

2.7 Overview

Following a qualitative approach, an emergent constructivist grounded theory with critical analysis was applied to data obtained from the TCC case study, focus group and associated documentation. The literature study emphasises the core elements of the research problem and these focus areas are addressed in the next two chapters. Chapter 3 addresses dolomite and the mitigation of associated anthropogenic factors and Chapter 4 examines the issue of low-cost housing.

CHAPTER 3: DOLOMITE, NOT DYNAMITE

3.1 Introduction

> *"That thing is the dynamite. It was planted under the ground so that this place can easily blow up" – concerned resident.*

The background, research questions and objectives, as well as the research methodology for this thesis have been described in the two preceding chapters. In response to the research question, namely which hazards associated with dolomite pose a risk to residents living in areas underlain by dolomite, this chapter examines the hazards associated with dolomite and sinkholes and the risks accompanying this hazard. The point of focus is the risk that dolomite and sinkholes present in built areas, specifically low-cost housing developments in the study area and the mitigation measures associated with these hazards.

On Sunday the 3rd of August 1964 a sinkhole swallowed the home of the Oosthuizen family in the Blyvooruitzicht Township near Carletonville. The family of five and their domestic worker perished and disappeared in the abyss forever (Gutiérrez *et al.*, 2007; GSSA, 2011). This event shocked a nation and created a first awareness of the hazards associated with unstable dolomitic areas to residents previously unaware of the time bomb under their homes, schools and churches. The hazards associated with dolomite in built areas have always been known to mining companies and geologists alike, but after this event the topic was open for discussion and in the public domain.

In developing an awareness plan to communicate the hazards associated with dolomite to residents, there has to be a commitment to the scientific information that defines and quantifies the risk for residents (Morgan *et al.*, 2002:34). This entails studying the scientific literature and reports on dolomite and sinkholes to understand the phenomenon in such a way that the essential and critical data can be extracted. It should be appropriate for conveying the hazards and associated risks clearly and transparently, especially the anthropogenic factors that can be mitigated in low-cost housing areas.

This is an intellectual approach that relies on natural science and expert inputs (Walaski, 2011:43). This approach may be complicated and lengthy and is not suited to all risk awareness contexts. For the purpose of this study, the expert model is called a scientific information and data framework. This framework forms the basis of the messages and awareness actions to help communities mitigate the risk associated with dolomite and sinkhole formation in built areas. The application of the framework is described at length in Chapter 5 of this study.

3.2 Chemical composition, weathering and dissolution of dolomite

3.2.1 Chemical composition

Dolomite is a sedimentary rock that formed in shallow oceanic conditions during the Archaean to Paleoproterozoic period approximately 300 million years ago (Department of Water Affairs, 2009:4). In the South African context, President T.F. Burgers, the second president of the Republic of Transvaal of the ZAR in 1871, first referred to dolomite when he discovered the Wonderfontein Eye (Wagener, 1984).

Dolomite is a calcium- and magnesium-rich carbonate mineral expressed as the chemical combination $CaMg(CO_3)^2$ (Pretorius, 2012a:5). However, the rock type dolomite refers to dolomitic limestone (Department of Water Affairs, 2009:6). This dolomitic rock consists of mineral dolomite mixed with calcite (calcium carbonate, $CaCO_3$) and magnesite (magnesium carbonate, $MgCO_3$) (Department of Water Affairs, 2009). The dolomite occurring within the TCC forms part of the Malmani Subgroup of the Chuniespoort Group that in turn forms part of the Transvaal Supergroup (Department of Water Affairs, 2009:6; Oosthuizen & Richardson, 2011:15). The area has alternating bands of insoluble chert and dolomite (Richardson, 2013:9). Meintjes (2016:7) indicates that limestone is the first precipitation, where after dolomite forms, with chert forming as secondary product. Within the dolomite rock there is a network of fractures, joints and faults that form passages for water to infiltrate the rock (Richardson, 2013:13).

3.2.2 Weathering and dissolution

Rain or water that infiltrates the dolomitic rock is charged with carbon dioxide (CO2) from the atmosphere. As it passes through the soil where the concentration of CO2 may be 90 times more than atmospheric CO2, it forms carbonic acid (H_2CO_3). In its flow, the carbonic acid (H_2CO_3) gradually dissolves the dolomite by leaching carbonates, which causes the joints, faults and fractures to widen and to eventually form networks of cavities (Oosthuizen & Richardson, 2011:1; Ford & Williams, 2013:58; Richardson, 2013:13). As the water percolates through the horizontal layers of material, the material that is the least densely compacted weathers away first, forming voids in between the competent material (Pretorius, 2012a:6). The dissolution of dolomite to form cave systems and cavities may take thousands or more years (Meintjes, 2016:7). After weathering or dissolution, the insoluble residues are chert, iron and wad (Nel & Haarhoff, 2011:9).

3.2.3 Dolomite instability

The stability of dolomite refers to its inherent susceptibility for the formation of sinkholes and subsidences and the magnitude and the frequency with which they can occur within a specific context of triggering mechanisms such as the geology, geomorphology and geohydrology of the area (Buttrick *et al.*, 2014:123).

3.3 Hazards associated with dolomite

3.3.1 Karst formation in dolomite

The term *karst* originated in the 19th century and is derived from the Slovene name “Kras” for the plateau on the border of Slovenia and Italy, close to the Adriatic Sea. In Italian it is called “Carso”, and in German, which was then the prevalent scientific language, it was eventually called karst (Cernatič-Gregorič & Zega, 2010:109).

The dissolution of dolomite rock to form cavities, voids and cave systems are called karst features (Buttrick *et al.*, 2001b:27). This network of caves is typically buried underneath layers of weathered material or products of the weathered dolomite (Buttrick *et al.*, 2001b:27). These residual weathered layers can also consist of wad (“weathered after dolomite”) (Meintjes, 2016:8). Wad is a blue-grey or black and fine grained, highly compressible and erodible silty clay, consisting of manganese and iron oxides (Buttrick, 1986; Nel & Haarhoff, 2011:10).

The processes that govern the karstification process can be attributed to the following factors (Klimchouk & Aksem, 2005; Gutiérrez *et al.*, 2007:1010,1011):

- the minerology and lithology of evaporates and aquifers;

- the texture and the structure of the soluble rock and aquifers;
- the saturation index, temperature, volume and chemical composition of the water being exposed to the evaporates;
- the groundwater conditions and its flow; and
- variations in piezometric levels (water table fluctuations).

This highly weathered dolomite terrains are known by geologists as karst terrains. Karst terrains feed a rich variety of plants and animals and are well known for its fresh underground water sources. They can be found worldwide. The map in Figure 3-1 by Williams and Fong (2010) indicates the incidence of karst landscapes worldwide, while Figure 3-2 indicates the occurrence of dolomite in South Africa and Figure 3-3 highlights the occurrence of dolomite in North West province where the study area is located:

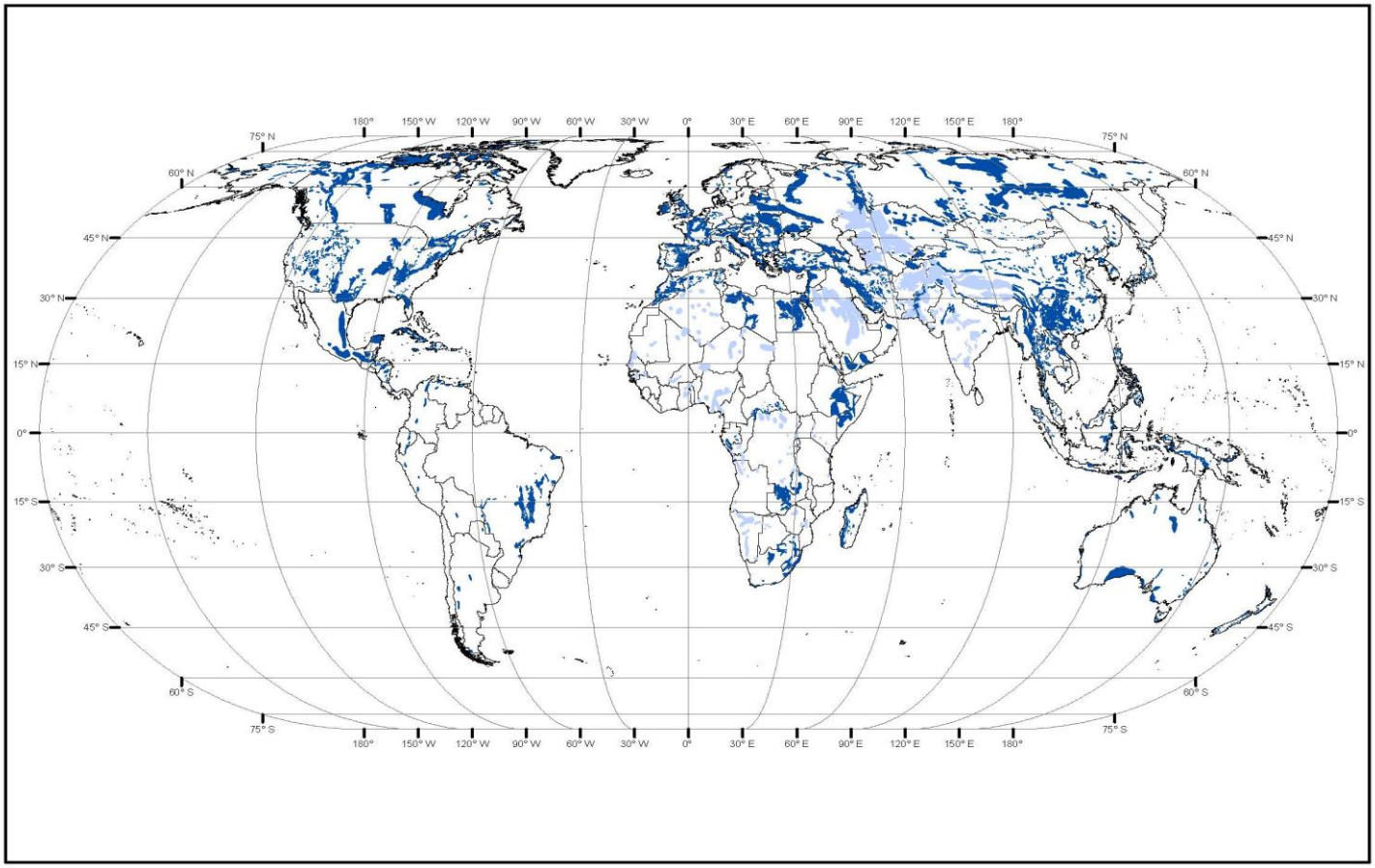


Figure 3-1: World Karst map (Williams & Fong, 2010)

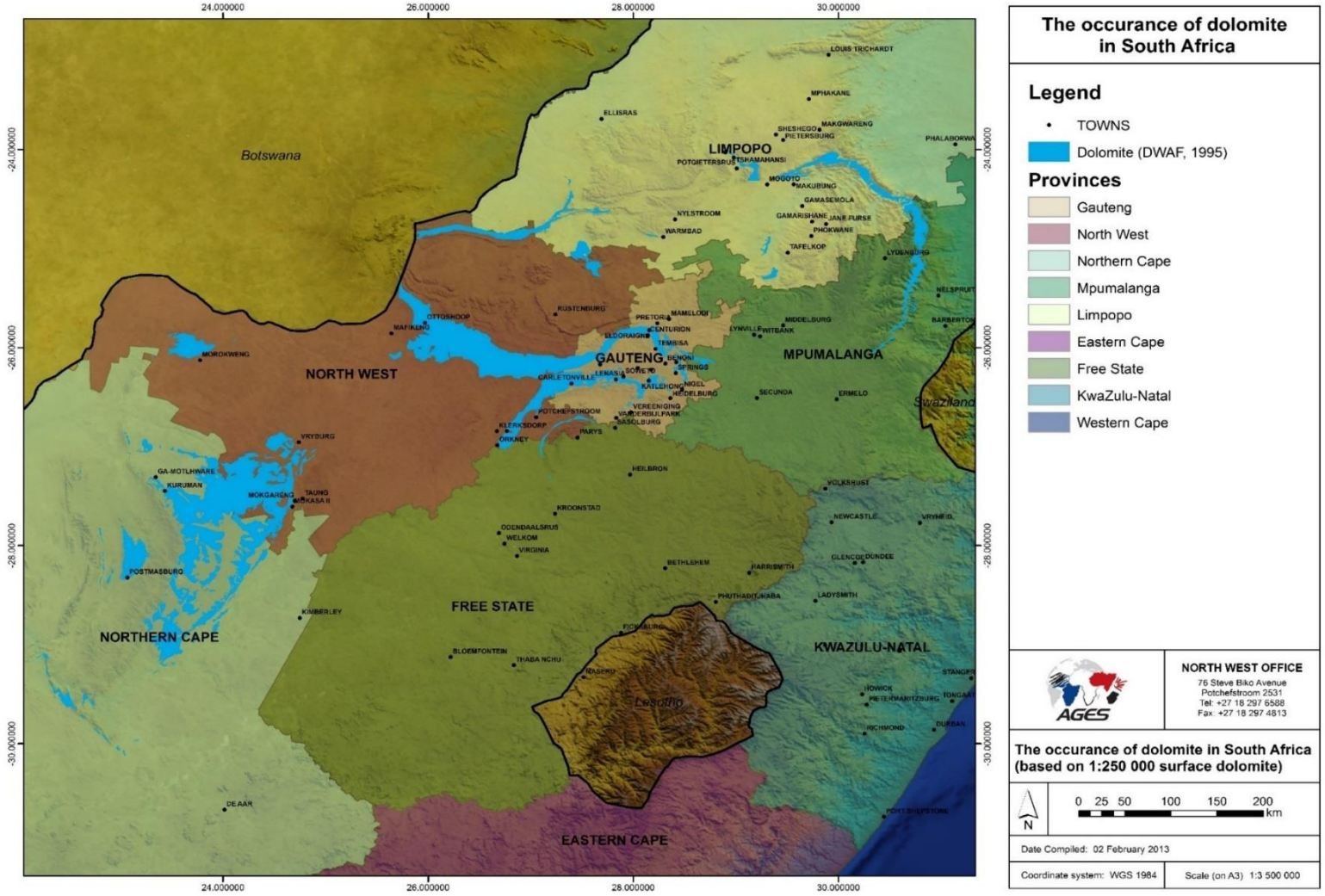


Figure 3-2: The occurrence of dolomite in South Africa (AGES, 2013b)

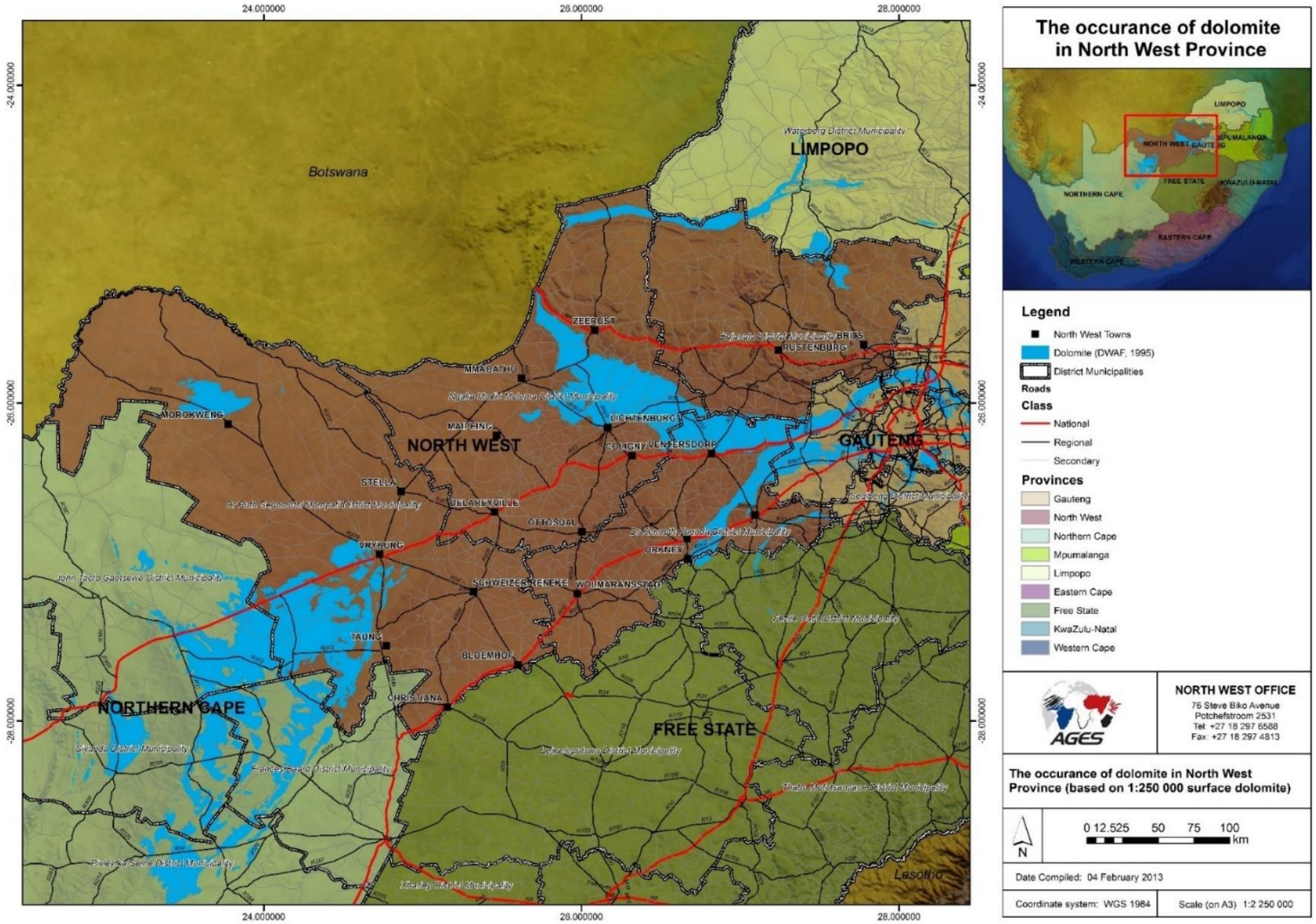


Figure 3-3: The occurrence of dolomite in the North West province (AGES, 2013b)

3.3.2 Subsidence

When wad and other residues come into contact with water, it collapses or dissolves and flows into the cavities and cave systems. This dissolution of the cave roof leads to ground movement on the surface (Buttrick *et al.*, 2001b:27). These ground depressions are usually sub-circular and can be hundreds of meters wide and very deep (Gutiérrez *et al.*, 2007:1008). These depressions can generally be identified by concentric cracks along the borders (Pretorius, 2012a:8).

3.3.3 Sinkholes

The dissolution of rocks, whether on the subsurface or on the surface, coupled with erosion and deformation processes may lead to closed depressions known as sinkholes or dolines (Gutiérrez *et al.*, 2007:1008). The term doline is commonly used in European contexts, and literature favours the use of the term sinkhole. Sinkholes are formed due to the presence of carbonate or evaporite karst. In the study area, sinkholes form due to dolomite, which is a carbonate karst.

Sinkholes can be described as natural or man-induced collapses of groundcover that occur because of the synergy of predisposing factors in the presence of triggering mechanisms (Intrieri *et al.*, 2018:3). Sinkholes can be formed by a variety of processes such as bedrock dissolution, rock or soil collapse (Waltham *et al.*, 2007:26). When one of these processes occur, the sediment can be washed into the ground, lowering the ground surface, or the dissolution of the rock may lead to the collapse of the ground to form a hole in the ground surface (Waltham *et al.*, 2007:26).

Cavities form slowly over geological time and grow larger as groundwater or the ingress of water lead to further dissolution. The collapse can happen when the cavity grows too large to support the weight of the roof of the cavity and the roof collapses. In another scenario, the cavity is filled with groundwater, and when the groundwater levels fluctuate, the cavity can no longer support the overlying burden of sediment (Nel & Haarhoff, 2011:10).

Sinkholes cause damage to infrastructure and, buildings with great associated financial implications and loss of lives (Gutiérrez *et al.*, 2007:1008). Buttrick *et al. (2001b:27)* describe this process as a catastrophic movement of the surface of the ground that can happen within seconds and without prior warning signs. Smaller sinkholes (5 m to 20 m in diameter) are usually formed as a result of the ingress of water, while larger sinkholes (more than 20 m in diameter) are usually the result of dewatering (Buttrick & Roux, 1993:291).

Waltham *et al*. (2007:27) classify sinkholes as follows:

Table 3-1 Sinkhole classification (Waltham *et al.*, 2007)

Sinkhole Classification	Description
Solution sinkhole	Very large, occurs through natural lowering of the floor through dissolution of soluble rock.
Collapse sinkhole	Rapid collapse of the roof of the cavity, falling inward.
Caprock sinkhole	Rapid collapse of insoluble material overlying soluble rock cavities, falling in cavity.
Dropout sinkhole	Rapid collapse of overlying soil into fissures in soluble rock underneath the insoluble material.
Suffusion sinkhole	Non-cohesive material washed into fissures in soluble rock over a prolonged period.
Buried sinkhole	Soil filled surface dissolution

Adapted from (Waltham *et al.*, 2007)

In South Africa the prevalent sinkhole types are collapse and caprock sinkholes (Pretorius, 2012a:8). The effect of these sinkholes is that they collapse in a catastrophic way without warning signs (Gutiérrez *et al.*, 2007:1008). Sinkholes can also be classified according to their surface manifestation or size. Table 3-2 below presents the classification system according to Buttrick (2014:124):

Table 3-2 Sinkhole sizes

Maximum diameter of surface manifestation	Terminology
‹ 2 m	Small-size sinkhole/subsidence
2-5 m	Medium-size sinkhole/subsidence
5-15 m	Large-size sinkhole/subsidence
›15 m	Very large-size sinkhole/subsidence

Adapted from (Buttrick *et al.*, 2014)



Image 3-1: Sinkhole at the Carletonville reservoir (Own image)

3.3.4 Inherent susceptibility

The classification of the inherent hazard susceptibility of an investigation site describes the potential for a specific size sinkhole forming in a proposed scenario. The scenario would include land use and subsurface conditions such as piezometric levels (Buttrick *et al.*, 2011b:2). Inherent hazard refers to the potential for mobilisation of the blanketing layer covering a void or potential void and the characteristics of the mobilising mechanisms (Buttrick *et al.*, 2011b:2). The hazard of sinkholes forming is divided into high, medium and low categories of hazard and then further into eight inherent hazard classes that indicate the probability of a sinkhole forming as well as the possible sinkhole size.

Engineering and geological dolomite stability investigations are generally undertaken prior to development to determine the inherent hazard classes as defined by the eight hazard classification areas and their definitions listed in Table 3-3 below.

Table 3-3 Inherent hazard classification (Buttrick *et al.*, 2014)

Inherent Hazard Class	Characterization of area
Class 1 Areas	Areas characterized as reflecting a low inherent susceptibility of sinkhole and subsidence formation (all sizes).
Class 2 Areas	Areas characterized as reflecting a medium inherent susceptibility of small-size sinkhole and subsidence formation
Class 3 Areas	Areas characterized as reflecting a medium inherent susceptibility of medium-size sinkhole and subsidence formation
Class 4 Areas	Areas characterized as reflecting a medium inherent susceptibility of large-size sinkhole and subsidence formation.
Class 5 Areas	Areas characterized as reflecting a high inherent susceptibility of small- size sinkhole and subsidence formation.
Class 6 Areas	Areas characterized as reflecting a high inherent susceptibility of medium-size sinkhole and subsidence formation.
Class 7 Areas	Areas characterized as reflecting a high inherent susceptibility of large- size sinkhole and subsidence formation.
Class 8 Areas	Areas characterized as reflecting a high inherent susceptibility of very large-size sinkhole and subsidence formation.

The hazard rating scale defines the view of society or society's level of tolerance of the measured hazard (Buttrick *et al.*, 2014:125). Low inherent susceptibility will have a tolerable hazard rating, while medium and high susceptibility will have an intolerable hazard rating. Changes in the karst environment due to anthropogenic causes may accelerate the formation of sinkholes or trigger reactivation of sinkholes (Gutiérrez *et al.*, 2007:1013). When sinkholes are formed this way, it is referred to as an induced sinkhole. The anthropogenic factors and how they affect the formation of sinkholes are discussed in 3.3.5.

3.3.5 Anthropogenic factors

Karst landscapes are intrinsically fragile and vulnerable to especially environmental change induced by human behaviour (Andriani & Walsh, 2009:312; Day, 2010:138). Anthropogenic factors are induced by human behaviour. An activity on the surface can rapidly translate into major events at subsurface level (Parise *et al.*, 2004:569). Historically, literature has focused on pre-existing cavities (Elrod, 1898; Vineyard & Williams, 1968), but recent literature focuses more on external factors that put already vulnerable locations under stress (Green, 2015:177). On a macro level, urbanisation and deforestation have an impact on karst landscapes, but they find expression in ingress of water, ponding and substandard development on dolomite.

Karst instability occurs as a natural phenomenon over years, but it is significantly expedited and amplified by the actions of humans living on karst (Andriani & Walsh, 2009:314; Oosthuizen & Richardson, 2011:4). Human activities that cause anthropogenic susceptibility in areas with high inherent susceptibility include all actions that would introduce the ingress of groundwater, the abstraction of water from dolomitic aquifers, or destabilisation of the overburden on unstable dolomitic areas, which can result in the formation of sinkholes or subsidences (Department of Water Affairs, 2009:5; Oosthuizen & Richardson, 2011:4). Water leaks that erode the soil cover, groundwater abstraction and fluctuation of the groundwater table all lead to the instability of dolomite (Department of Water Affairs, 2009:5).

In Caribbean karst landscapes the effect of anthropogenic factors such as forest clearing, agriculture, urbanisation and tourism are acute and long term (Day, 2010:141). Urbanisation in the Caribbean near cities such as Jonestown, Montego Bay and Bridgetown creates increasing pressure on karst landscapes (Day, 2010). Sinkholes may also be masked by anthropogenic activities, for example filling of sinkholes and development on sinkholes (Gutiérrez *et al.*, 2007:1014). These corrective measures may even exacerbate sinkhole formation due to the added weight of the overburden.

Activities that usually coincide with development disturb the metastable conditions in the karst. The following possible scenarios may occur:

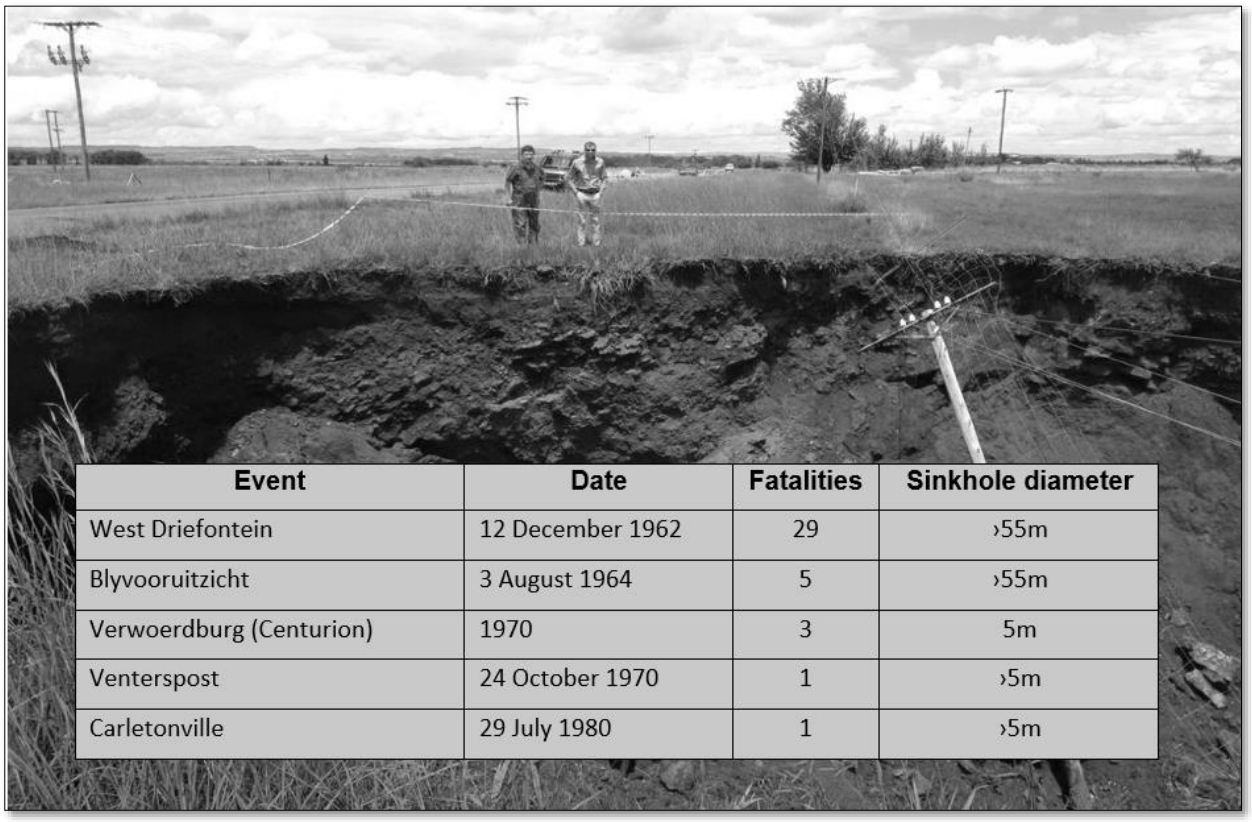
- There could be artificial alterations to natural drainage patterns.
- There could be induced water concentrations.
- Flow velocities may be either retarded or enhanced.
- Superficial soil material may be disturbed, affecting permeability (Buttrick & Roux, 1993:291).

In order to illustrate the effects of anthropogenic factors on dolomite stability, Buttrick *et al*. (2011a:1133,1134) studied the coincidence of sinkhole and subsidence events with service types such as bulk pipelines, storm water systems and buildings from 1984 to 2004. Some of the findings were as follows:

- A total of 167 events occurred on 108 km of water and bulk pipelines (1.35 events per kilometre of pipeline).
- A total of 255 events were reported along 225 km of storm water pipelines (1.14 events per kilometre of storm water pipes).
- Thirty-eight per cent of all events recorded coincide with structures and affect the stability and integrity of the buildings.
- A total of 220 331 m² buildings were lost as a result of 246 events.

The above-mentioned study by (Buttrick *et al.*, 2011a:1133, 1134) highlights the coincidence of sinkholes and infrastructure on dolomite. This also leads to a loss and damage of infrastructure. This is supported by Roux (1984), who conducted a study of 10 sinkholes on the western side of Pretoria, where it was found that all the sinkholes were induced by anthropogenic factors. Tragically, the impact of anthropogenic factors on dolomite also claims lives. Table 3-4, summarised from Buttrick and Roux (1993:292), confirms this:

Table 3-4 Sinkhole fatalities in South Africa



Event	Date	Fatalities	Sinkhole diameter
West Driefontein	12 December 1962	29	›55m
Blyvooruitzicht	3 August 1964	5	›55m
Verwoerdburg (Centurion)	1970	3	5m
Venterspost	24 October 1970	1	›5m
Carletonville	29 July 1980	1	›5m

Over the past 60 years, sinkholes and subsidences have been reported to and by government departments, municipalities, consultants and companies, but not all incidents were reported if they occurred on private or public land (Oosthuizen & Richardson, 2011:21). In South Africa, 2500 known sinkholes have occurred. The Wonderfontein spruit adjacent to the study area is known as the “sinkhole farm”, the location where 37 people have lost their lives in sinkholes since 1962.

The effect of anthropogenic factors on sinkhole and subsidence formations is illustrated in the following figures (Fig 3-4 to 3-7):

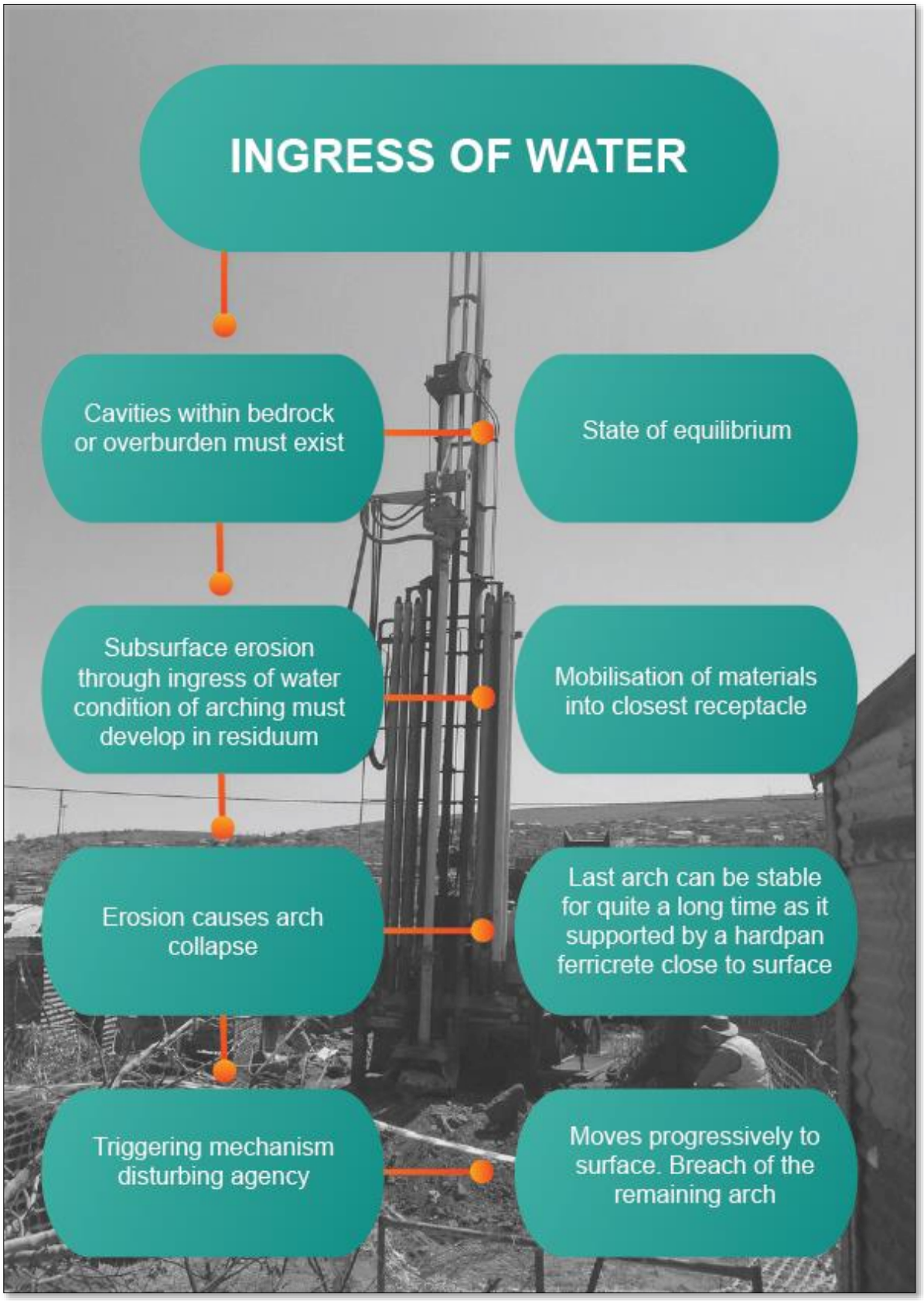


Figure 3-4 : Anthropogenic factor: Sinkhole scenario – ingress of water (Own representation)

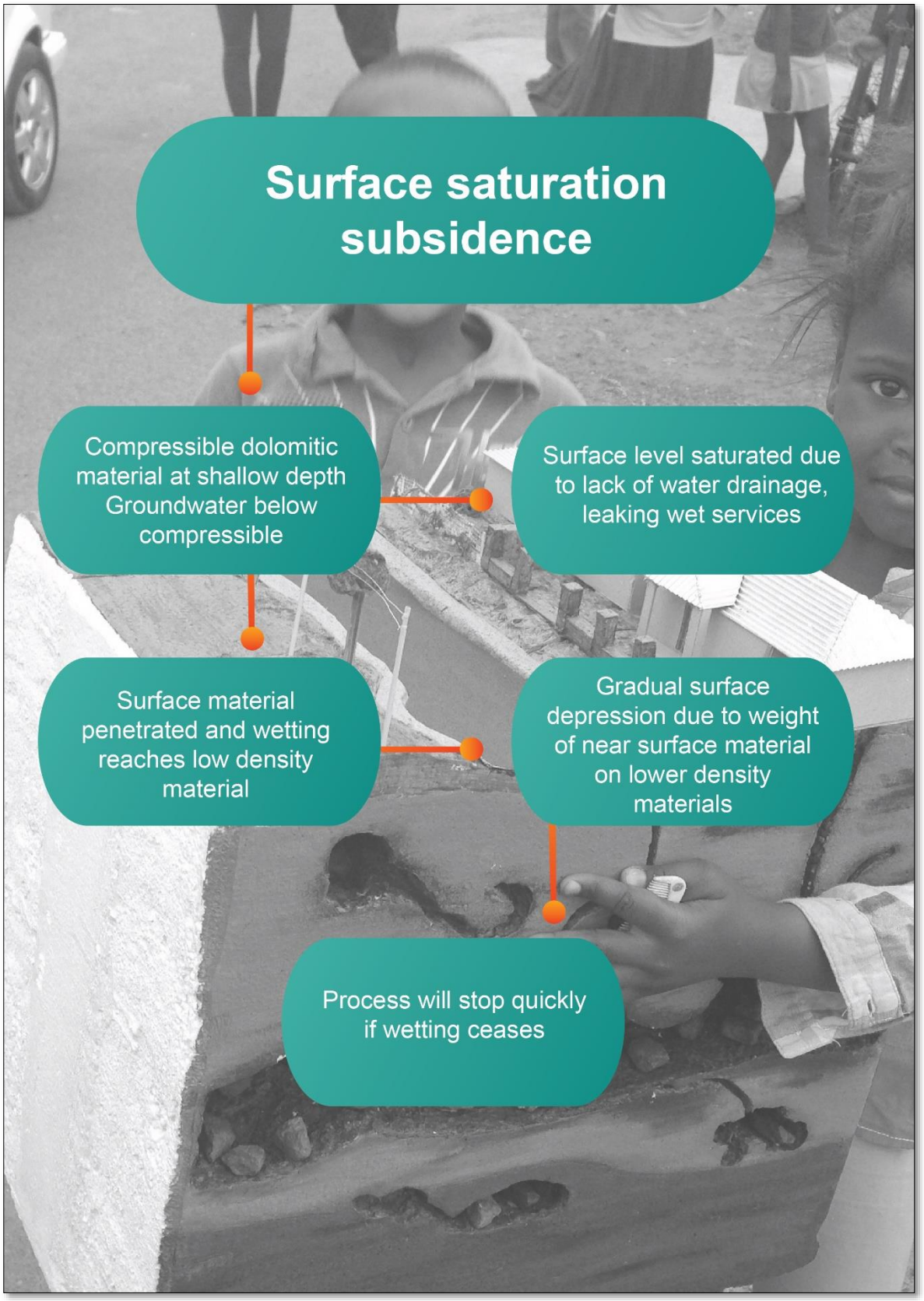


Figure 3-5 : Anthropogenic factor: Subsidence scenario – subsurface saturation (Own representation)



Figure 3-6 : Anthropogenic factor: Sinkhole scenario – dewatering (Own representation)

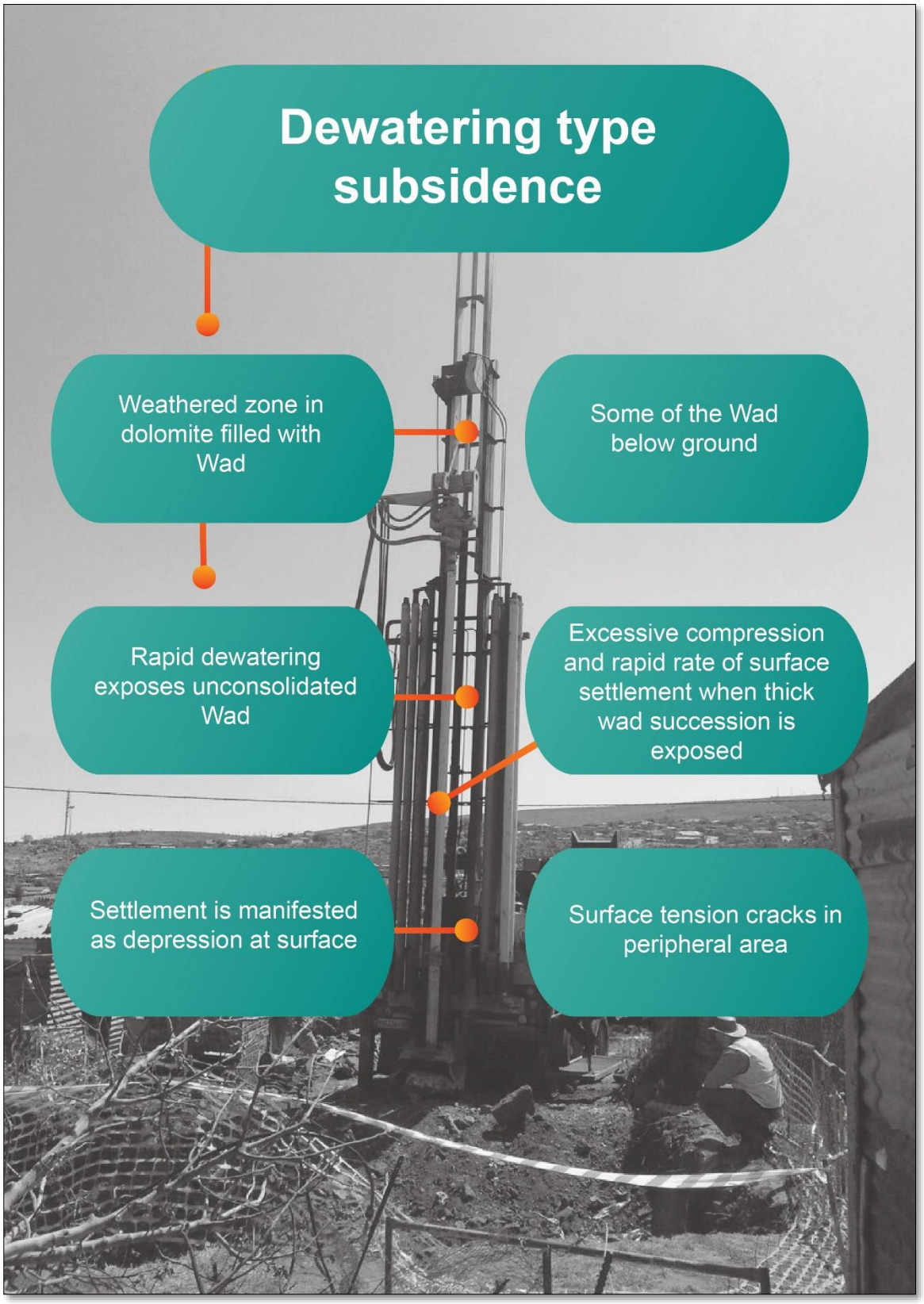


Figure 3-7 : Anthropogenic factor: Subsidence scenario – dewatering (Own representation)

An example of what happens when one of the anthropogenic factors, in this case ingress of water through leaking infrastructure, is not mitigated and a sinkhole develops:



Image 3-2: Sinkhole Carletonville reservoir (Own image)

Subsequently, the effect of anthropogenic factors on the risk to vulnerable communities are examined in more detail in 3.4 of this chapter.

3.4 Anthropogenic susceptibility of built environments

3.4.1 Risk assessment

When assessing the risk of a hazard such as dolomite, scientists use the traditional risk equation (Bell, 2003:206):

$$R = \sum H \times E \times V$$

The hazard component (H) in this formula refers to the risk associated with a hazard, such as unstable dolomite as a function of the inherent susceptibility. E represents the exposure to the hazard and V the vulnerability of the affected community. Buttrick *et al*. (2014:131,132) suggest that the definition of this hazard be broadened to include the anthropogenic susceptibility. When assessing the inherent classification of areas underlain by dolomite, the anthropogenic factors are included. Of the sinkholes that form, 99% can be attributed to anthropogenic factors within a

site deemed to exhibit high inherent susceptibility (Buttrick *et al.*, 2014:131). The following equation is an attempt to include the anthropogenic risk and consider the capacity and resilience (as described in Ch. 5) of the affected communities living on dolomite. Also see Fig. 3-8 for a graphic illustration of the outcomes of this equation on disaster risk.

$$\text{Risk} = \text{Fn}\frac{\text{Dolomitic Hazard } \times \text{Vulnerability} \times \text{Anthropogenic Susceptibility}}{\text{Capacity}}$$

When considering classification in built areas, the anthropogenic factors are pivotal to the assessment. Dolomite risk management areas (DRMA) are used as a means to qualify and quantify the inherent susceptibility classification in conjunction with the anthropogenic susceptibility of each zone. Each DRMA is linked to a specific classification in conjunction with applicable mitigation and management measures. In older areas where dolomite stability investigations (DSI) have not been conducted, this becomes problematic as the hazard of non-compliant and aging infrastructure cannot be quantified sufficiently (Pretorius, 2012a).

The declining levels of service delivery and aging infrastructure contribute to the anthropogenic susceptibility of the built environment underlain by dolomite. The risk presented by the inherent susceptibility and influenced by the anthropogenic susceptibility is amplified by the vulnerability of communities living in low-cost housing underlain by dolomite. The coincidence of sinkholes with water bearing services is illustrated in a study by Buttrick *et al.* (2014:126), pointing to a 98% rate of sinkhole formation occurring on water leaks over a 20-year period.

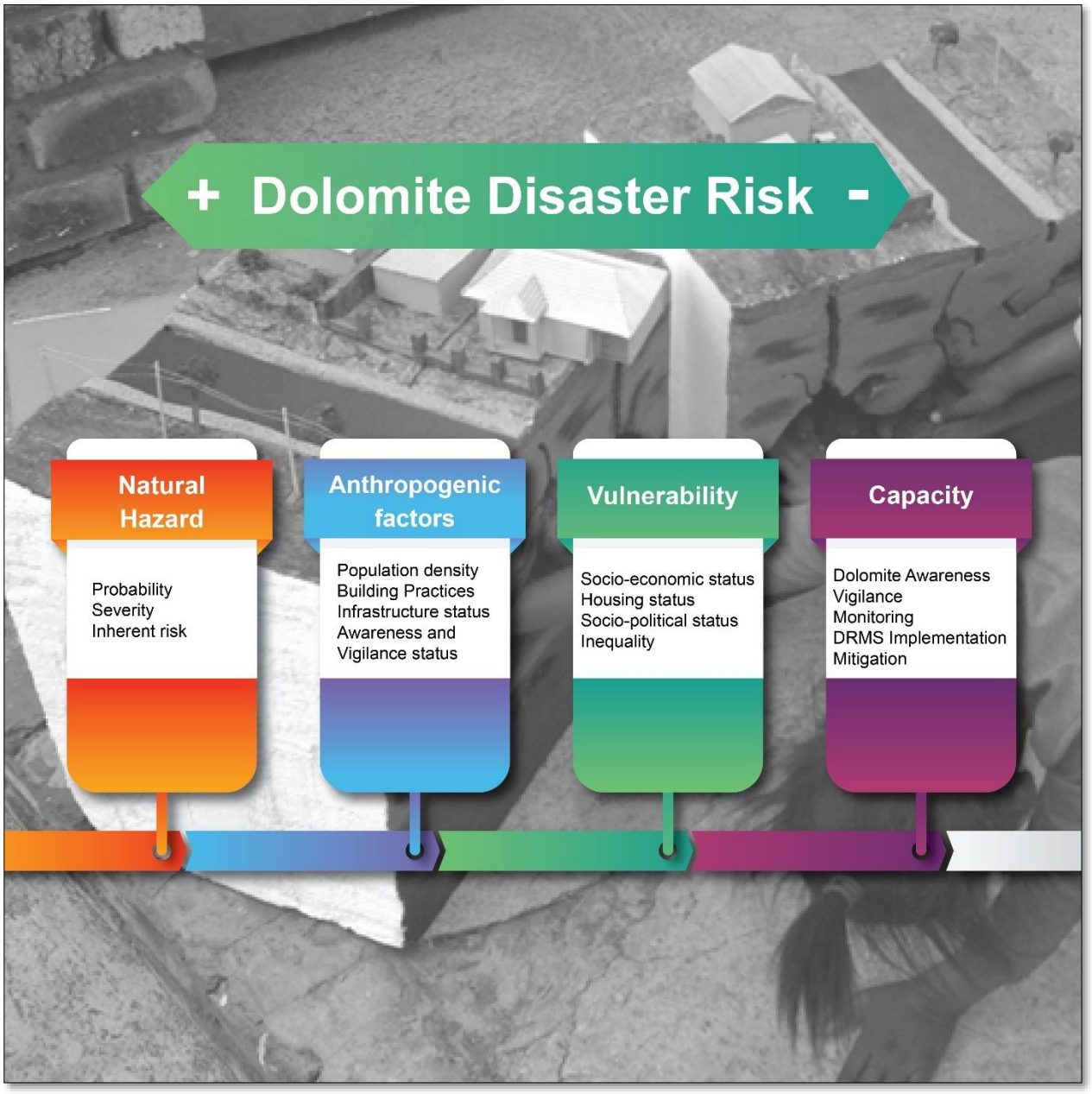


Figure 3-8 Dolomite risk equation as amended by the inclusion of anthropogenic factors and capacity (Muller, 2017).

3.4.2 Dolomite stability investigation (DSI) to determine hazard and risk

A DSI is done to determine the hazard and the risk posed by karst. By doing this, the area at risk can be delimited and the triggering mechanisms defined so that risk reduction actions can be implemented (Intrieri *et al.*, 2018:2). The method used in the study area is the scenario supposition method. The method of hazard zoning requires that the available information, geophysical data, borehole data and geohydrological information gathered during an investigation

are collated and reviewed (Buttrick *et al.*, 2001a; Gutiérrez *et al.*, 2007:1013). This permits the formulation of a perspective concerning the characterisation of the stability of a site. The predominant mobilising agencies considered in the investigation are major groundwater level fluctuations (>6 m), ingress water, ground vibrations and gravity. A generalised list of evaluation factors is made to evaluate the risk of sinkhole formation:

- Receptacle development space,
- nature of the blanketing layer,
- mobilisation potential of the blanketing layer and
- bedrock morphology.

Any voids in the dolomite bedrock or the overburden capable of receiving mobilised materials act as receptacles. Receptacles are assumed to be present as no reliable geophysical tool exists to establish the location of these features.

The information gathered from pneumatic percussion boreholes, including penetration times, air loss, hammer action, etc., combined with geophysical and geological information are used to formulate a general idea of the degree of cavity development.

The potential sinkhole development area refers to the expected maximum size sinkhole that may conservatively speaking be expected to form if continuous ingress of water occurs. This is also related to the depth of the receptacles. Geophysical surveys, especially the gravity survey, combined with borehole logging data mostly guide the assessment of this factor.

The nature of the material covering the receptacles, whether they are above or in the dolomite bedrock, determines the susceptibility of the subsurface material to erosion by ingress water. The presence of materials such as shales or intrusives, which can act as aquitards, reduces the mobilisation potential and enhances stability. In the case of considerable groundwater level fluctuations, the susceptibility of the soil material to mobilisation, is actively influenced by the level of the original groundwater level in the subsurface profile. Buttrick (1992) and Buttrick *et al*. (2001) provide guidance for the evaluation and determination of the hazard.

The hazard of sinkhole formation is expressed in three broad categories, namely in terms of low, medium and high hazard areas. Thereafter, the land is characterised in terms of eight standard inherent hazard classes (see Table 3-3). These classes denote the chance of a sinkhole occurring, as well as its likely size (diameter). The larger the inherent hazard class number, the greater the chance of a sinkhole occurring and the larger its potential size, should it occur. The following actions are included in a DSI:

- collation of existing available data;
- geo-environmental desktop study: regional and geological setting
- geological mapping: verification of desktop study, site visit to existing instability features, survey data;
- aerial photographs, especially large-scale colour stereographic images (Gutiérrez *et al.*, 2007:1014)
- geophysical surveys: e.g. gravimetric and electromagnetic surveys (Bennett & Doyle, 1997:200);
- siting for drilling, rotary percussion and logging;
- on site characterisation;
- geo-hydrological study and modelling;
- status of infrastructure and developments on dolomite;
- age, location and status of water-bearing infrastructure (Buttrick *et al.*, 2014:125);
- abandoned services to be decommissioned (Buttrick *et al.*, 2014:125);
- interpretation and evaluation of the above data;
- DRMA zoning;
- DRMP with technical specifications and recommendations; and
- compilation of DRMS.

The methodologies referred to above emerge from a limited dataset to make temporal and spatial predictions and must be seen as non-corroborated hypotheses. These predictions implicitly suppose that future subsidences will have a corresponding rate and behaviour to already existing indices (Gutiérrez *et al.*, 2007:1022). The anthropological factors may have an increasingly greater impact over time. It is therefore advisable to evaluate the predictive reliability of the susceptibility zonation with predictive modelling (Gutiérrez *et al.*, 2007:1022). The final decision is made in one of three broad categories, namely whether the risk ascribed to the particular hazard rating is intolerable, tolerable or a broadly acceptable risk. Experts such as Sartain *et al.* (2014:637) prefer to work with the ALARP (as low as reasonably practicable) principle. This method uses the data obtained to do a quantitative risk assessment as to upper and lower thresholds of the risk. and the method also aims to ascertain what the required performance of the mitigating measures should be.

3.4.3 Mitigation

The most effective strategy to mitigate the risk of dolomite and sinkholes are naturally the avoidance of areas riddled by this hazard. When vulnerable people, infrastructure and homes

occupy areas underlain by dolomite, the hazard should be mitigated or the vulnerability decreased, or both processes must be addressed simultaneously (Gutiérrez *et al.*, 2007:1023).

The following mitigation measures can be used to reduce the severity of the anthropogenic impact and therefore the hazard:

- Preventing fluctuation of piezometric levels
- Lining of canals and ditches
- Control of agricultural and other irrigation systems
- Diversion of surface run-off
- Effective drainage
- Sinkhole and subsidence remediation
- Filling cavities with grouting
- Grout curtains beneath dams, screening and avoiding water movement underneath infrastructure

Researchers such as Gutiérrez *et al.* (2007:1024), Buttrick *et al.* (2011b); Buttrick *et al.* (2014) and Potgieter *et al.* (2016) consider non-structural measures such as the following:

- Monitoring in vulnerable areas
- Risk awareness programmes
- Warning signs and fencing of sinkhole-prone areas

3.5 Risk awareness

Most research projects focus on scientifically gathering and analysing it to determine the hazard and thereafter the risk, but very few consider the effect of risk awareness on all communities living on dolomite, but especially vulnerable communities. Intrieri *et al.* (2018:1) reason that the low global awareness of sinkhole risk is due to the localisation of sinkholes. There are sinkhole-prone areas, but the rest of the world is unaffected, unlike landslides, which is a very widespread phenomenon.

Buttrick *et al.* (2014:128) allude to the fact that dolomite risk management has a substantial effect on the reduction of sinkhole formation. Verifiable evidence has recently become available from which it is clear that recent catastrophic failures of precautionary measures failed because of a lack of awareness, dedication and training (Buttrick *et al.*, 2014:128). Chapter 5 provides an overview of risk awareness and how it is applied in vulnerable communities.

The anthropogenic factors as described in this chapter are summarised in Table 3-5. While researching the different sources, the difference in denotation of what anthropogenic risk refers to became apparent. In an effort to disentangle the difference in emphasis, I divided the anthropogenic factors into levels. This thesis mainly works with the meso level as second order origin leading to the microlevel effects, which can be mitigated by the involvement of communities and other local stakeholders.

Table 3-5: Anthropogenic factors represented on levels

Anthropogenic factors on dolomitic land in built areas		
Macro level	**Meso level**	**Micro level**
Climate change	Flooding	Over-burden on karst
Climate cycles	Drought	Ingress of water
Socio-Economic factors specifically poverty	Groundwater abstraction	Fluctuation of piezometric levels
Population levels	Low-cost housing	Ponding of water
Political climate	Densification of urban areas	Sub-surface instability
Informal settlement patterns	Aging infrastructure	
Illegal settlement patterns	Lack of wet services	
	Grey water run-off	
	Settlement on dolomitic ground	
	Sub-standard building practices	
	Increased mining activities	
	Illegal extensions and backyard structures	

(Original work: Muller, 2020)

3.6 Overview

The way karst landscapes are formed over geological time makes it part of the landscape to such an extent that communities living among the dolomitic outcrops do not realise how deceptive this landscape can be, especially when anthropogenic factors coincide with these natural features. In order to mitigate these factors, communities have to be informed and understand the scientific processes that cause the hazardous environment. The caveat is that it should be presented in a

way that addresses their levels of vulnerability and makes them active participants in the risk they share. The next chapter discusses the characteristics and incidence of low-cost housing to gain an understanding of how these structures affect dolomite, and ultimately how these living arrangements define the vulnerability of the community residing in them (see Ch. 5).

CHAPTER 4: THE HIGH COST OF LOW-COST HOUSING

4.1 Introduction

One of the key indicators of whether a country is on its way to eradicating poverty is adequate provision of housing (Manomano *et al.*, 2016:111). The provision of housing entails giving homes to those who are the most vulnerable. Corruption, maladministration and misuse of houses by benefactors (Manomano *et al.*, 2016:115) have rendered a portion of the vulnerable citizens even more vulnerable. In the previous chapter, the hazards associated with dolomite and the potential risk to communities have been explained. In this chapter, the focal point is the development that takes place on dolomitic land, and more specifically the low-cost housing categories. Housing is a complex issue with different dimensions. There are interactions between nature and socio-economic factors in relation to housing, and these can never be seen in isolation (Turok & Borel-Saladin, 2016:389). Storie (2016) uses the term “low-income housing”, but I prefer to use “low-cost housing”. Examining anthropogenic factors, it is ostensibly the quality of the structure and where it is located that define the issue. Although this thesis describes people living in those structures in terms of vulnerability, it is not always due to low income that low-cost housing is erected. Further on in this chapter, the motivation for erecting these structures is examined.

The occurrence of sinkholes in built karst areas worldwide is not only restricted to vulnerable communities. Affluent areas are also affected by this phenomenon. In 2014 the National Corvette Museum in Bowling Green, Kentucky, partly collapsed into a huge sinkhole, and eight Corvettes plunged into the sinkhole (Mann, 2015a:12). In 2013 the Summer Bay Resort in Clermont, Florida, USA, in close proximity to Disney World, experienced the collapse of some of its buildings and guests had to be evacuated (Mann, 2015a:12). The remediation of these sites cost millions of dollars, which will most probably be recovered from future revenue from the tourism industry. The Corvette museum reopened its doors the day after the event occurred, as the site was stabilised by then (Mann, 2015a:32). The outcome when a sinkhole of this magnitude occurs in a low-cost development in South Africa is vastly different. This chapter examines the forces at work when dolomite and sinkholes converge with low-cost housing developments, as well as the risk it represents to communities.

There is a worldwide tendency to avoid dolomitic land for housing development and to rather re-purpose it for parks or conservation (Fleury, 2009). However, in areas such as Florida in the USA, it is almost impossible to avoid karst areas. Clint Kromhout from the Florida Geological Survey (Luscombe R, 2013) says that if you live in Florida, sinkholes are a fact of life. Figure 4-1 shows the occurrence of sinkholes in Florida and Figure 4-2 the hazard zonation of Florida state.

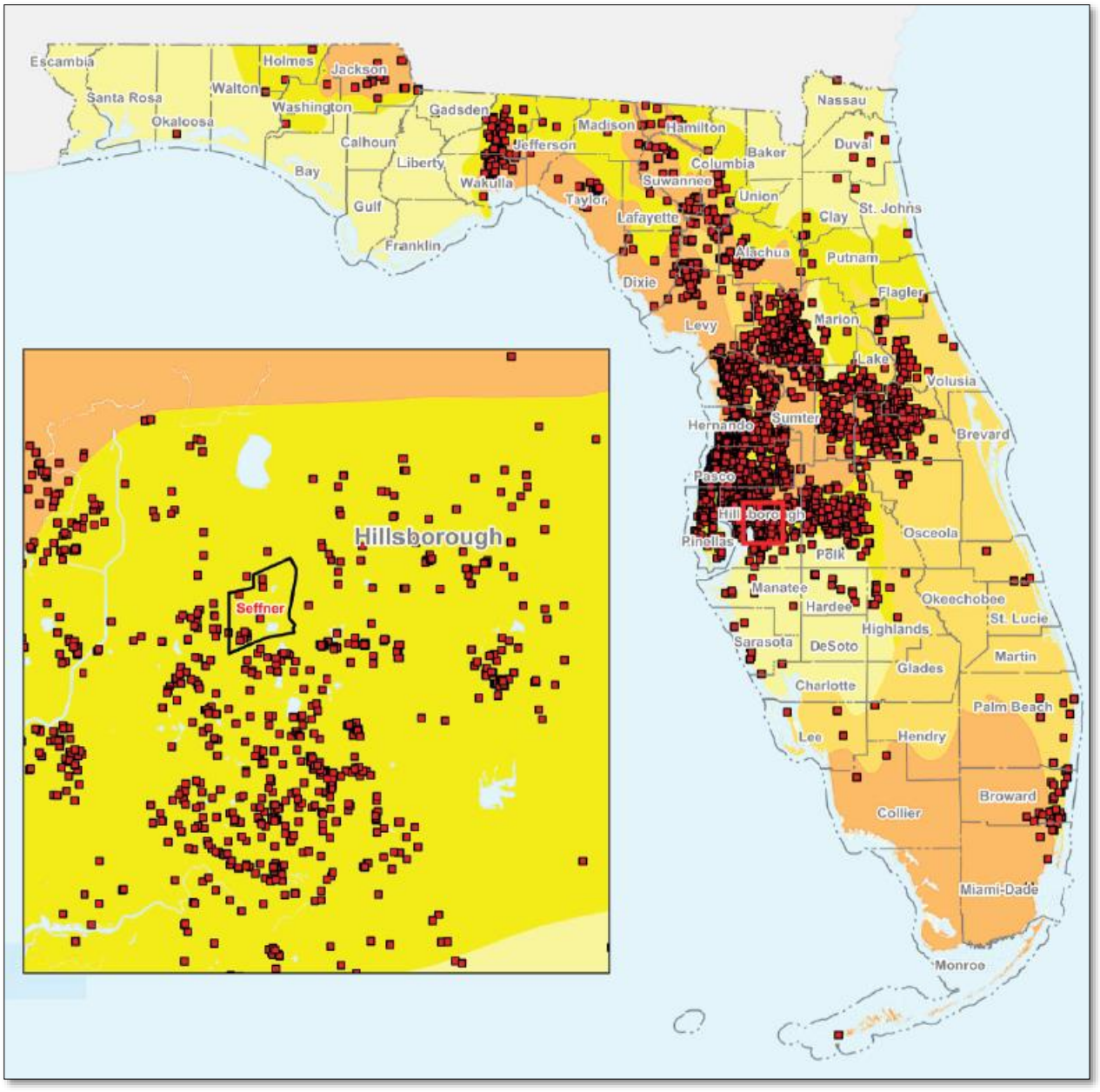


Figure 4-1: Florida sinkhole map (https://www.riskmanagementmonitor.com/disappearing-florida-the-risks-of-sinkholes-in-the-sunshine-state/)



Figure 4-2: Florida sinkhole zones (Florida Geological Survey Map Series 110)

In Khutsong, Merafong, Gauteng province, adjacent to TCC, 25 000 households had to be resettled and the only available land was on dolomite with a lower risk zonation. The blue area in Figure 4-3 indicates a medium risk area, while the yellow represents a medium to high risk area. Since then the development has been completed and resettlement has taken place.



Figure 4-3: Khutsong resettlement area (Human Settlements Presentation, 2008)

The TCC faces the same predicament in that there is very little land available in the municipal area for housing projects and many housing projects are already located on areas with high risk zonation. The TCC case study in Chapter 5 addresses this issue in detail.

In addition to the huge demand for low-cost housing confronting local municipalities, there is the reality of insufficient funding, geological and engineering complexities and scarcity of available land for development. Development is done with the focus on short-term urgency to provide housing, while the hasty provision of infrastructure, which has to last many years, is not sustainable and has no future upgrading potential (Storie, 2016:43).

Karst areas complicate township development due to the absence of general karst awareness, but also partly due to the difficulty of determining the correct boundaries of the risk area and precise location of where sinkholes might occur (Intrieri *et al.*, 2018:1). Karst greatly affects the land use authorisations from the side of government (Heath & Constantinou, 2015:503). This also means that some land use applications will be denied, or applicants will have to comply with strict and sometimes costly measures to mitigate the risk of developing on dolomite.

Gauteng province is the province with the most sinkhole incidents in South Africa especially due to urbanisation and expansive built-up areas (Heath & Constantinou, 2015:504). The study area

located in the North West province of South Africa is rapidly urbanising. The urbanisation of other previously sparsely habituated karst areas has the potential to change the incidence statistics in the near future.

4.2 Dolomite regulatory environment

Regulations were established for township development from 1965 onwards. A developer became obligated to appoint a competent person to make recommendations concerning foundations, layout, density, services and precautionary measures after assessing the site (Heath & Constantinou, 2015:505). A competent person is an experienced engineering geologist or engineer. DSI reports also have to be submitted to the Council for Geoscience as required by the Geoscience Act (100 of 1993), and in return they provide independent expert advice and a review to government and the general public (Heath & Constantinou, 2015:505). In this capacity, the CGS was asked to do DSIs for different affected local municipalities, including the Sonderwater township development in the study area, Ikageng. This was done under the auspices of the Organised Local Municipalities Act (52 of 1997).

The CGS compiled guidelines, which were converted into national standards, now make them effective for mandatory adherence. These standards are the SANS 1936 Parts 1–4:2012 (SANS, 2012a), which now guide authorities and consultants on how to approach the dolomitic hazard for all green fields developments as well as existing built areas.

Land use and development densities are considered for approvals on dolomite on the basis of an acceptable level of risk as the need for land is greater than available land without karst complications. The term "**acceptable risk**" describes the likelihood of an event whose probability of occurrence is small, whose consequences are so slight, or whose benefits (perceived or real) are so great, that individuals or groups in society are willing to take or be subjected to the **risk** that the event might occur. Up to now these approvals were focused on the formal housing land use applications, with some recent changes to address informality in the SANS (2012a). The approval process did not foresee the proliferation of informal housing, backyard dwellings and illegal settlements that would mushroom throughout urban parameters (Storie, 2016:30). A study by Moshodi (2014:99) indicates that structures are being erected around the newly resettled community living on dolomite in Khutsong.

The back engineering of approvals and adherence to dolomite standards in built areas are so complicated that the options tend to hover between evictions and the indefinite postponement of decision making regarding the future of these settlements, especially when considering the high cost associated with DSIs and the difficulty drilling rigs have with entering between structures

erected in close proximity to each other. The third option is a resettlement, such as Sonderwater (Ikageng, TCC), Khutsong (Merafong, Gauteng) and Bapsfontein (Mpumalanga). In the first two cases the resettlement was implemented as planned, but in the case of Bapsfontein the Constitutional Court ruled in favour of the residents and the resettlement was unsuccessful (Storie, 2016:30). The reasoning behind the ruling was that the risk was defined as being immanent, but in many years after being declared immanent, no events have occurred. They have therefore been removed without due course. Any of these options may lead to civil unrest and protests by stakeholders. The worst-case scenario is that evictions may lead to residents not having the basic right to a place of shelter. Evicting someone because they are living on high risk dolomite may be perceived as contravening that right. It must therefore always be approached on solid legal grounds.

The core elements of regulations concerning development on dolomite centres on geotechnical, town planning and engineering solutions, conditions, and the human element. As a result, the community element is somehow lost in translation (Storie, 2016:54; Muller, 2017).

In the USA there are basic state laws that address water withdrawal from ground and surface resources but some states, such as Florida and Alabama, have local and county ordinances that regulate storm water management and land use (Mann, 2015b:66). Few regulations directly address karst terrains, with the exception of Greene County Missouri where karst and sinkholes are addressed extensively in its zoning ordinances. Land developers must also adhere to building and planning regulations when developing on karst (Mann, 2015b:66).

4.3 Low-cost settlement types

4.3.1 Low-cost housing in South Africa

Low-cost housing in South Africa is a multifaceted issue. This study only discusses those facets that relate to the anthropogenic risk on dolomitic ground. Storie (2016:27) defines low-income housing in terms cost of living in a certain area in relation to household size and possible income potential. She then quantifies it by certain monetary parameters paired with erven size (Storie, 2016:28).

The Human Settlements White paper sets the following vision for housing in 2050:

“By 2050 visible outcomes from effectively coordinated spatial planning systems will have transformed human settlements in South Africa into equitable and efficient spaces with citizens living in close proximity to work with access to social facilities and essential infrastructure.” (Department of Human Settlements, 2015).

The Constitution of South Africa, 1996, declares that every resident has the right to adequate shelter. This is the foundation of all human settlement sectoral policies (Gardner & Graham, 2018:1). The government has built 3.2 million houses through housing projects to redress past inequalities in housing provision and projects to close the gap in housing provision caused by rapid urban densification (Boureaux,2008:17). As urbanisation has maintained its momentum, the backlog increases continuously (Boudreaux, 2008:17). Despite this process of densification and development, it has been clear that the racial dimensions in peripheral communities have remained the same, the low-cost settlements house mostly black communities (Gardner & Graham, 2018:37).

In addressing the backlog in housing and creating good living conditions, several policies and legislation have been developed of which some are now redundant, but have shaped the housing landscape:

- Reconstruction and Development Plan – 1994
- The Housing Act, 107 of 1997
- The Peoples Housing Process – 1998
- Revised National Housing Code – 2009
- The Social Housing Policy – 2005
- Inclusionary Housing Policy – 2007
- Breaking New Ground – 2004
- Integrated Development Plans
- Less Formal Township Establishment Act, 113 of 1991
- Development Facilitation Act, 67 of 1995

All the above acts create an enabling environment for housing development, but as mentioned in section 4.1, two processes are at work:

- The demand for housing surpasses supply; and
- Land on urban perimeters are in short supply.

The ideal house to build on dolomite with a tolerable hazard is on average 13 m x 13 m, or at least 170 m² (Kirsten *et al.*, 2009). This also entails compliant town planning, foundations, building practices, and water bearing infrastructure. When considering low-cost housing, it is difficult to adhere to these dimensions.

The images below show the housing categories that have been occupying high-risk dolomitic land in South Africa.

4.3.2 Social housing



Image 4-1: Ministers Nosiviwe Mapisa-Nqakula and Nomaindia Mfeketo hand over apartments to military veterans in Fleurhof, Johannesburg (Image GCIS)

Social housing is an option for households earning between R1 501 and R15 000 per month. The households pay a rental amount in relation to their income (Manomano *et al.*, 2016:114; Mkuzo *et al.*, 2019:3). This scheme is managed by a Social Housing Institution. These housing options are usually well planned, keeping to regulations, and has as yet not created problems in conjunction with dolomite, but the problematic period is after development, when infrastructure needs to be maintained, and bad workmanship starts showing.

4.3.3 Subsidised housing



Image 4-2: RDP development, Ikageng (Image ASP Potgieter)

Under the Reconstruction and Development Plan (RDP), local government, built homes for disadvantaged citizens. It is administered by means of a waiting list at the municipal level. In developing countries, and in South Africa due to its Apartheid land use policies, townships have developed on the urban perimeters that house mostly lower income households.

Some low-cost housing is left incomplete and housing beneficiaries have to source contractors to complete their homes. Some have leaking roofs, foundations and walls cracking, and structural collapse is evident (Manomano *et al.*, 2016:114; Mkuzo *et al.*, 2019:3). Lack of expertise, poor communication of the standards that has to be followed and using emergent contractors all lead to structural failure (Othman & Mydin, 2014:2). Contractors are not held accountable as there are not enough qualified inspectors and management to certify compliance (Mkuzo *et al.*, 2019:4).

The process of implementing the housing policy was enforced on all fronts due to a preoccupation with numbers. The focus was on keeping to the promised political delivery output and not on

quality. It seems that for the government, the success of the housing policy depended not on community participation, but on meeting the housing targets, specifically the one million mark (Pottie, 2003:136). The Department of Housing (1997:3) asserts that statistics show that "*the current housing policy has taken root* and there is a strong upward trend (both for subsidies approved and for money spent) and *the outlook for an increased delivery tempo is very positive"*.

"However, in ideological terms, government's engagement with the market and a preoccupation with its own financial constraints indicated that the balance was shifting ever further in favour of achieving results on the ground, whatever the cost to the original 'people driven' understanding of the RDP" (Pottie, 2003:136). When visiting new RDP projects in dolomite affected areas, the state of newly built houses confirm that this statement is still in effect.

4.3.4 Informal housing

"An impoverished group of households who have illegally or without authority taken occupation of a parcel of land (with the land owned by the Council in the majority of cases) and who have created a shanty town of impoverished illegal residential structures built mostly from scrap material without provision made for essential services and which may or may not have a layout that is more or less formal in nature" (HDA 2013:9).

4.3.4.1 Informal settlements



Image 4-3: Informal settlement, Ikageng (Own image)

The spatial fragmentation inherited from past land use planning has led to people having to travel great distances to access job opportunities and amenities. Disadvantaged families often choose to live in informal settlements illegally in locations that present life-threatening geological risks (Picarelli, 2019:35). These groups devise their own response to extended waiting periods and their desperate need for housing by working around state regulations to settle in informal ways (Turok & Borel-Saladin, 2016:391).

Informal settlements usually develop under one of the following conditions:

- People move to urban centres to find jobs. They temporarily settle as close as possible to the urban area to search for opportunities. They may also follow family to live as close as possible to family.
- People who have been waiting for RDP houses for many years construct temporary housing while waiting for their erven or RDP home. The average waiting time is five years,

but it can be longer as people who take part in land invasions or pay bribes to officials jump the queue (Picarelli, 2019:39).

- Mass migrations may also take place when news of new opportunities spread. When the neighbouring Matlosana Municipality in North West province was put under administration, the rumour was spread that the TCC had loads of money and would be able to provide better opportunities. In a period of three to four days, a new settlement developed on dolomitic ground in Promosa (TCC). I was witness to the influx of vehicles carrying informal building material. The noise of hammering drowned all conversation. Suddenly unoccupied land was home to thousands of people. The people had structures to live in, but no running water or sanitation.
- Officials sometimes, for a fee, award people with erven that have not been serviced or where the risk has not been quantified. The families then settle illegally and informally.

As there are as yet no regulations for the establishments of informal settlements, there is significant risk when these structures are erected on dolomitic ground. Formalising these developments are costly and mitigating the risk is a lengthy and sometimes impossible task. The decision to provide an informal settlement located on dolomite with basic services may put the residents at more risk than they were. Municipalities provide temporary toilets, communal taps and public lighting.

The Breaking New Ground (BNG) policy has replaced the RDP policy and has begun to address informal settlements with five primary ends in mind (Department of Human Settlements, 2004; Gardner & Graham, 2018:3):

- **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."

- **Integration and spatial restructuring, which is seen as critical to sustainable human settlements**

"… utilising housing as an instrument for the development of sustainable human settlements, in support of spatial restructuring." There is also an institutional dimension as integration is both intragovernmental (within a sphere of government) and intergovernmental, requiring integrated planning and coordinated investment.

- **Housing assets**

The subsidy house as an asset to the beneficiary household is introduced as a concept for the first time: *"ensuring property can be accessed by all as an asset for wealth creation and empowerment" and "supporting the functioning of the entire residential property market to reduce duality…"*

- **Upgraded informal settlements**

For the first time the need to upgrade informal settlements is recognised. The BNG calls for the progressive eradication of informal settlements and urban inclusion: *"informal settlements must urgently be integrated into the broader urban fabric to overcome spatial, social and economic exclusion."*

- **Scaling up the social housing programme**

The policy clarifies the importance of social housing to upgrade and integrate city development. BNG sees this form of tenure as enhancing "*the mobility of people and promoting a non-racial, integrated society."*

The ideal would be to reduce informal settlements' vulnerability by providing the services needed to make their living conditions on dolomitic ground sustainable. In informal low-cost settlements the population and dwelling density is also higher than in planned settlements (Storie, 2016:149). This places a heavier burden on the high-risk dolomite.

4.3.4.2 Backyard dwellings



Image 4-4: Backyard dwelling on dolomite in Ikageng (Own image)

Backyard structures do not use the provided wet services, but they tap into it illegally by creating their own connections (Oranje *et al.*, 2020:2). People who need to live closer to work or are waiting for housing live in these structures and pay rent to the owner. In some cases, the owner extends a home by building a backyard structure.

4.4 Anthropogenic factors in low-cost housing areas

Karst instability occurs as a natural phenomenon over years, but it is significantly expedited and amplified by the actions of humans living on karst (Andriani & Walsh, 2009:314; Oosthuizen & Richardson, 2011:4). Human activities that cause anthropogenic susceptibility in areas with high inherent susceptibility include all actions that would introduce the ingress of groundwater, the abstraction of water from dolomitic aquifers, or destabilisation of the overburden on unstable dolomitic areas, which can result in the formation of sinkholes or subsidences (Department of Water Affairs, 2009:5; Oosthuizen & Richardson, 2011:4). Water leaks that erode the soil cover,

groundwater abstraction and fluctuation of the groundwater table all lead to the instability of dolomite (Department of Water Affairs, 2009:5).

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4.4.1 Hazard zonation in low-cost housing areas

According to Storie (2016:28), hazard zonation in dolomitic areas where low-cost housing already exists or is earmarked for development can only be an approximation as it is based on drill hole analysis and can only venture to indicate voids, aquifers and subsurface patterns. When a development was established before a DSI had been done, it is very difficult to assign risk and plan mitigation actions.

4.4.2 Infrastructure

The city of Oviedo in Spain has known about the presence of karst for more than five centuries, yet it was only in 1998 that the reality struck home. City planners decided to construct housing for the socially disadvantaged and completed the project in 1965. In 1998 water was pumped from an aquifer nearby and it caused great structural damage to the housing development. The damage was such that the residents had to be resettled while remediation and rebuilding took place (Mann, 2015a:36). The effect was that they could only return to their homes four years later. In South Africa, the problem is often that communities settle informally first, so that the government is pushed into a choice between increasing the risk by providing essential services, or risking social unrest by attempting to relocate the entire settlement.

The systemic inattention to the upgrading and regular maintenance of infrastructure in densified urban areas that are already over capacitated will place a fiscal burden on municipalities (Gardner & Graham, 2018:42). This is even more true for developments on dolomite.

4.4.3 Implications of low-cost housing on dolomite for awareness

In the south-eastern parts of the USA, sinkholes are a well-known phenomenon. The state of Kentucky keeps a database of sinkholes that occur, as well as information on the research and remediation of sinkholes (Mann, 2015a:31). When the sinkhole in Bowling Green described in 4.1 occurred, it was a huge surprise to the owners, and it ultimately created more awareness worldwide of the damage caused by sinkholes.

Costly property and structural damage occur in the event of sinkholes forming. These costs cannot be carried by either the government or residents living in low-cost areas, as they are already overburdened. Existing sinkholes develop drainage points into a sub-surface system and any contaminants deposited would most probably enter the groundwater system and pollute water wells and springs (Zhou & Beck, 2008:837). This only serves as motivation for all stakeholders involved to create maximum risk awareness in order to mitigate the anthropogenic effects of hazardous dolomite and sinkholes.

Table 4-1 summarises the coincidence of low-cost housing on dolomitic ground and the anthropogenic effects associated with it.

Table 4-1: Coincidence of low-cost housing on dolomitic ground and anthropogenic effects

Low-cost housing type	Planning, guidelines compliance	Infrastructure compliance	Building Compliance	Maintenance and sustainability	Anthropogenic consequences
Informal Housing: Informal/Illegal settlements	No adherence to guidelines and planning permissions	Non-compliant for wet services Standpipes with no grey water drainage	When on previously penned erven, may adhere to stand size Non-compliant to building permissions and regulations	None	Ponding Ingress of water Surface saturation subsidence
Informal Housing: Backyard Dwellings	May share in some planning guidelines for example Township establishment.	Partially non-compliant municipal wet services may be modified Grey water and sewerage drainage not compliant	Stand density and load bearing potential may be exceeded. Structure without foundation on dolomitic ground	Mostly none due to temporary status	Ponding Ingress of water Surface saturation subsidence
Subsidized Housing	Planning and guideline compliance by Government	Contractor credentials not certified Contractor compliance not guaranteed	Contractor credentials not certified Contractor compliance not guaranteed	Cracks in homes, mostly ignored or owner fixes	Leaking infrastructure Major infrastructure failure Ingress of water Ponding Surface saturation subsidence
Social Housing	Planning and guideline compliance by Government	Contractor credentials not certified Contractor compliance not guaranteed	Contractor credentials not certified Contractor compliance not guaranteed	Unknown	Leaking infrastructure Major infrastructure failure Ingress of water Ponding Surface saturation subsidence

Communities living in locations that have the potential to be dangerous exhibit lowered capacity to cope with the consequences and to recover from events that can increase the financial and physical risk (Storie, 2016:33). The lowered capacity and resilience and vulnerability are discussed in Chapter 5.

The anthropogenic risks associated with dolomite have been addressed in Chapter 3. Chapter 4 examined the incidence and quality of low-cost housing in South Africa, with the focus on those aspects that influence the mitigation of anthropogenic factors on dolomite.

The preliminary basic assumptions that have been theorised from the literature study is that:

- high-risk dolomite in built areas is hazardous and poses a significant risk to communities living on it.
- anthropogenic factors amplify the risk to communities.
- the quality and incidence of low-cost housing is problematic, especially when located on hazardous dolomite; and
- in order to reduce the risk to communities living in low-cost housing on hazardous dolomite, the anthropogenic factors must be mitigated.

Chapter 5 unfolds the efforts that have been made to mitigate these anthropogenic factors in a community living on dolomite in low-cost housing. It also looks at projects that still have to be planned and implemented.

The following matters are addressed in Chapter 5:

- The background to the management and mitigation of hazardous dolomite
- The motivation for communities on dolomite being perceived as vulnerable and the consequences of that vulnerability
- The effect these vulnerabilities have on the mitigation of anthropogenic risk
- The pivotal role of creating risk awareness in order to mitigate anthropogenic risk
- The TCC case study and how the mitigation of the anthropogenic risk unfolded
- The outcomes and reactions of the community at risk in response to mitigation measures

CHAPTER 5: IKAGENG – BUILD YOURSELF[7]

5.1 Introduction

The features of karst and specifically dolomite that render it hazardous and pose a risk to communities and infrastructure are described in Chapter 3 of this thesis. Chapter 4 provides an overview of the low-cost residential dilemma in South Africa and the risk it creates in dolomitic areas. The coincidence of these two phenomena not only exacerbates the hazards of dolomite, but also complicates the mitigation of anthropogenic factors.

This chapter starts by framing the TCC community living on dolomite within the historical legacy of the Apartheid era.[8] The TCC forms part of the Dr Kenneth Kaunda District Municipality in the North West province of South Africa. In the TCC, dolomite is located to the west of Potchefstroom in portions of the Ikageng, Promosa and Mohadin townships (AGES, 2013c). The Apartheid government demarcated these areas for black, coloured and Indian residents respectively, and this distribution largely remains.

At relevant stages in the unfolding of the TCC study, the issues that have been identified as initial categories and their theory were isolated. The initial response to these categories in the form of planned and researched interventions follows. The interventions and reaction to the interventions, as well as new categories are introduced in a narrative way.

As mentioned before I planned, implemented and oversaw all actions mentioned here myself, but a team was needed to execute the actions.

E tlile ka letsatsi le lengwe[9]…

5.2 A legacy from the past

5.2.1 Ikageng

In the 1870s Potchefstroom saw the beginning of segregation according to race (Du Pisani, 2013) and with it forced social displacement (Kolobe, 2011:9). The South African Republic (ZAR) issued notices that the coloured community should be settled in a separate part of town. They were Afrikaans-speaking people of colour, descendants of freed slaves and the Xhosa-speaking

[7] The Setswana word Ikageng means to build together.

[8] This Afrikaans word meaning separateness became the name of the regime that lasted from 1948 to 1994. During this time racial segregation was enforced by law, and more specifically the Population Registration Act and the Group Areas Act of 1950.

[9] Setswana phrase: Once upon a time there was…

peoples. The area in Potchefstroom to which black residents were resettled was called Makweteng. In honour of the supervisor of this "location" (the term for non-white settlements during the Apartheid era), it was renamed in 1945 as Willem Klopperville (Kolobe, 2011:2). Shortly thereafter, the need arose to extend it. However, it was decided to rather relocate to the current location of Ikageng so that extensions could be made. An area west of Potchefstroom, adjacent to the Department of Defence, was identified for this purpose. A third of this land belonged to the Department of Defence and they were not enthusiastic about letting it go (Du Pisani, 2013).

In 1949 the Potchefstroom municipality gained permission to build the location. The Minister of Native Affairs appointed a committee to investigate alternative sites and conduct a public participation campaign. They agreed that the site earmarked by the municipality was suitable for a location. In the new location there was space for 6000 stands to house 40 000 people. The government intervened and forced the Department of Defence to include their adjacent property in the new location (Du Pisani, 2013). This aligned with the promulgation of the Group Areas Act in 1950 (Kolobe, 2011:3).

Land surveying and spatial planning was conducted, but no mention was made of the existence of dolomite[10]. Geological surveys had been done in this area and the existence of dolomite with its associated risks was known, but no legislation existed for township development to comply with risk quantification on dolomite (Muller, 2017:22). Authors such as Smit (2017:15) and Potgieter (2012) conclude that the establishment of Ikageng on dolomite predates our understanding of the link between dolomite, dewatering and sinkhole formation. The first houses were completed in 1954 and the area was renamed to Ikageng. By the early 1960s, the resettlement from Willem Klopperville to Ikageng had been completed (Du Pisani, 2013).

In a study by Kolobe (2011:18), residents who were relocated said: "*One day as I was sitting in the house and three white men in a car came and told me to move to Ikageng,"* and another added: *"Sometimes the kids were coming from school…only to find that their…their…their houses were not there and parents have been moved from their sites."*

The end of the Apartheid regime and the abolishment of the Group Areas Act meant that influx control was also abolished. Beginning from the 1980s, there was a huge influx of informal settlers into Ikageng. This meant that town planning and service delivery could not keep up with this added pressure. In 1994 Ikageng was enlarged with four extensions and three more had been added by 2008. These extensions were also established without prior geological and geohydrological investigation (Du Pisani, 2013).

[10] It is not clear whether the fact was missed or ignored during township establishment.

5.2.2 Promosa and Mohadin

In Klopperville, people of all races lived side by side. During the forced removals they were segregated along racial lines and two neighbouring areas were earmarked to this end. Ikageng must be seen in the context of these two areas, as all three areas have been affected by dolomite.

After the black residents were relocated to Ikageng, the suggestion was to proclaim Willem Klopperville as a coloured area. The newly formed *Waaksaamheidskomitee* (Vigilance committee), headed by Reverend Mieder Olivier, decided that this would not be desirable in the all-white Potchefstroom. Van Rensburg (2006:133-149) concluded that Reverend Olivier viewed the resettlement as an investment in the future of his people and essential to their survival. Du Pisani (2013) notes that shortly after the 1962 municipal election, the municipality was in agreement that the coloureds should also be relocated to an area west of Potchefstroom, adjacent to the Piekniekpoortje dam.

This area was named Promosa to indicate the promise of a new beginning with better living conditions. The families who were relocated were given R10[11] if they owned a house on their stand, and an additional resettlement fee of R10 (not even covering two months' rent in Promosa) (Van Rensburg, 2006:133-149). The residents were forcefully removed without any choice on their side (Muller, 2017:23).

In Ikageng people said: "*People just left their properties there. We had buildings there and we abandoned them and promised we will be compensated. They moved us here…into shacks, they called them hondehoks"*[12] (Kolobe, 2011:19).

Since the 1880s Indian businessmen had moved into Potchefstroom, settling close to the centre of town in an area known as the Asiatic bazaar. In 1958, the Group Areas Act Board decided to settle all Indians in the vicinity of the Asiatic Bazaar. The *Waaksaamheidskomitee* opposed this decision. The group objected to such an extent that the Group Areas Act Board revised their decision to support the municipality's proposal of an area adjacent to Promosa at the *Piekniekpoortjie* dam. This resettlement began in 1970 and Mohadin Extension 1 was proclaimed (Du Pisani, 2013).

[11] R10 is approximately $0,60.

[12] Afrikaans for dog box or doghouse.

5.3 Neighbouring troubles

Figure 5-1 indicates the regional dolomite, including the TCC as well as neighbouring Merafong in the Gauteng province. Khutsong, referred to in Chapter 3, forms part of the Merafong local municipality where mass relocations took place.

It was because of dolomite in Carletonville, adjacent to Khutsong, that an event occurred that would cause the country to take heed of dolomite, sinkholes and the devastating effects associated with it.

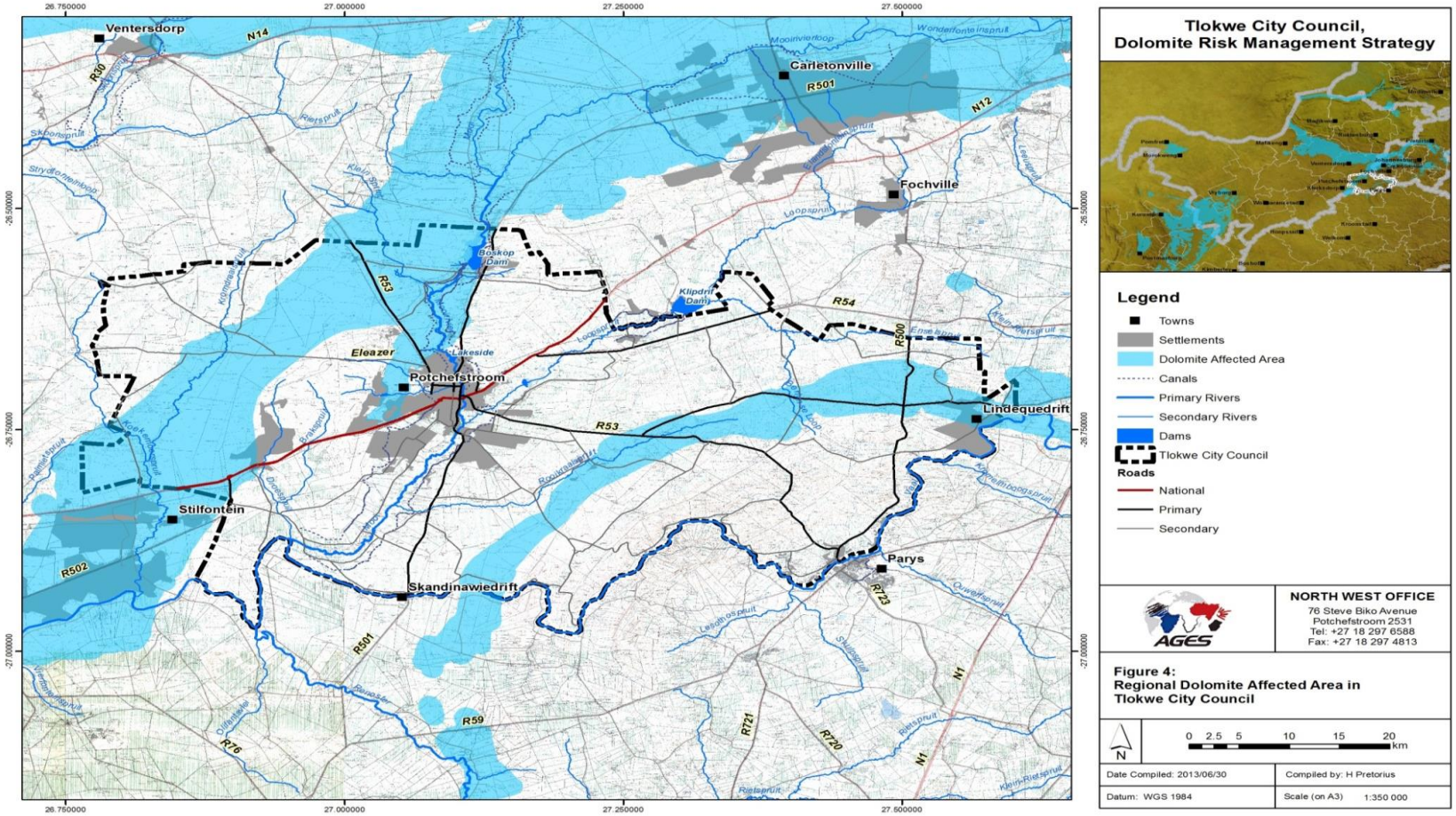


Figure 5-1: Regional dolomite, including the area administered by the Tlokwe City Council (AGES, 2013c)

Chapter 3 refers to the incident of the family who perished in a sinkhole in Blyvooruitzicht township. A resident at the time, Berend Schuitema (2012) described the feelings of the community as follows: "*For the mine bosses appeasing miners about their safety in their dwellings, as well as the neighbouring farming communities and informal settlements was not just a communal concern, but one that also impacted on the mining methods being used if not the viability of mining in the Far West Rand in general. Getting to know and understand the scale and the nature of the underground water problem was a priority. It was well known that pumping millions of gallons per hour from the new mines were at the root of the sinkhole problem. But what was not very well understood was the true extent and location of the water aquifers that had formed in the dolomite rock. Mining in the area was very much a question of serendipity and a hasty solving of engineering problems as they arose, giving little attention to long term implications*" (Schuitema, 2012).

In an attempt to cut the cost of pumping mine water to the surface, mining authorities made a decision to rather dewater four of the 11 dolomitic compartments. This caused groundwater to drop by hundreds of meters, the trigger for large sinkholes and the subsequent death of 30 plus people (Winde, 2006:381).

As a result, on the 12th of December 1962, a sinkhole fell in the West Driefontein mine, the richest gold mine in South Africa, and took the lives of 34 mine workers (Anon, 1962a). Reverberating from this incident were reports of many sinkholes in the area surrounding the mine. Huge cracks in houses made them uninhabitable and residents had to be relocated. The subsidences in the area received much publicity, but authorities did not heed the warning. The residents wondered whether one of their homes would be next in line. A local newspaper speculated that Carletonville might become a ghost town or disappear in a crater (Anon, 1962b), and the complaints from residents were resounding in these words. They had voiced their concerns in the past, but this only angered the city council and Chamber of Commerce. Even after this incident, the city council maintained that there was no cause for concern. They did agree to convene a meeting. The Department of Water Affairs appointed a committee to investigate subsurface water in the area.

At the time of this event, the newly built primary school had already shown huge cracks, but no measures were taken to address this situation. In January 1963, a part of the newly built school subsided and cracks widened. Some of the classroom doors could not close. The response from the Department of Education was to temporarily close the seven affected classrooms while drilling was done on site to investigate the subsidence, and school activities proceeded as normal. Homes across from the school subsided to such an extent that the residents were relocated (Anon, 1963).

The writing was on the wall, yet everyone was in denial. From this brief history preceding the Blyvooruitzicht (Carletonville) sinkhole, lessons can be learnt regarding risk awareness, but not all municipalities seem to have taken this lesson seriously.

The media voiced the concerns of residents and cognisance should have been taken of the warnings from this source. Although tell-tale signs of pending disaster were evident, a lack of awareness of the risk of dolomite and sinkholes led to negligence. The area described as the most surveyed piece of earth in the world, was researched by different geologists. However, they did not adequately convey the risks to their clients or consider it their responsibility to do more than surveying.

The concerns of the residents were not heard and acknowledged. Affected residents did not receive risk awareness training to monitor their own homes and to know which warning signs to react to. The approach to the management of dolomite and sinkholes was reactionary and not precautionary (Muller, 2017:48).

5.4 Mitigating the risk of dolomite and sinkholes

The mitigation of the risk associated with hazardous dolomite usually centres on the management of land use, engineering practices and building control. The implementation of environmental educational programmes is a well-established way of creating environmental awareness and are essential in any effort to mitigate the risk to all affected parties (Buskirk *et al.*, 1999; Gutiérrez *et al.*, 2007).

The draft SANS 1936 (2009) as well as SANS 1936 (2012) regulating development on dolomitic land requires that local authorities that administrate land underlain by water soluble strata such as dolomite must develop and implement a DRMS prescribed to local authorities underlain by dolomite that a DRMPr should be established and implemented. Geological studies in the jurisdiction of TCC indicated the presence of dolomite. Township establishment on dolomite as well as encroaching of settlements on dolomitic areas were a reality in the TCC jurisdiction. The process to establish a DRMPr was triggered by this regulation.

The most effective way of mitigation is naturally avoiding the subsidence areas and areas with high inherent susceptibility (Gutiérrez *et al.*, 2007:1018). As this is not always possible and in the case of TCC has not been adhered to in the past, preventative measures and regulations have to be introduced to regulate and limit development on hazardous dolomitic land. Dolomitic areas that have already been developed, have to be managed in order to reduce the effect of possible sinkhole or subsidence events (hazard) that can have catastrophic effects on vulnerable communities.

The TCC had to develop a DRMPr to mitigate the risk (AGES, 2010b; AGES, 2011; AGES, 2013e; AGES, 2013a; AGES, 2013b). Paukštys *et al.* (1999:1) argue that the most effective way to manage and implement these plans are when they are developed by the local administration. The TCC was not only required to manage and mitigate the dolomite risk in their jurisdiction but also the ideal agent to do so.

During 2009, the TCC introduced a phased DRMPr containing four processes within the framework of a 5 year three-phased implementation. During the first phase (Phase A) the hazard was identified and status determined, during Phase B the risk was quantified and evaluated and Phase C focuses on mitigation and management of the risk (Potgieter *et al.*, 2016:1018,1019). T

The DRMPr quantifies the hazard and determines the inherent and anthropogenic factors that increase the risk to residents and TCC (Potgieter, 2016:69). The DRMP guides the TCC on how to implement the strategy proposed for the management of dolomite risk with detailed recommendations on how to monitor, manage and mitigate the TCC dolomite risk (Potgieter *et al.*, 2016). The DRMS is the short, medium and long term framework and enforcing mechanism to put the DRMP into effect (Potgieter *et al.*, 2016). This allows the DRMPr to implemented in a systemised way.

In South Africa, the development of a DRMS still does not automatically include a separate risk awareness focus as is specified in the SANS (2012b). A study conducted within the Merafong Local Municipality (MLM) by Moshodi (2014:84) found that 66,6% of councillors indicated that they had not received dolomite risk awareness information and 83,3 % indicated that there had been no awareness campaigns. Twenty-nine out of 30 affected residents indicated that to their knowledge, no awareness campaigns had been conducted. The interpretation of these results could be problematic as is also apparent from the Tlokwe DRC study, since the consulting firm responsible for the Merafong DRMS has indicated that awareness actions had been conducted. Stakeholders from all the stakeholder groupings at times indicated that they had not received awareness training, while there was ample proof that they had received awareness materials on various occasions. What was noticeable in Merafong was that the risk awareness scope was quite limited.

Evaluating the management of dolomite in MLM, Van Eeden and Nealer (2011:133) concluded that the following trends are noticeable over several decades:

- The ignorance of the government and local government concerning dolomite;
- avoidance of dolomite issues by goldmining authorities;
- limited access to research findings for affected stakeholders;

- knowledge gaps created when consultants and government structures are succeeded by new persons; and
- deficits in cooperation between the institutional and affected stakeholders.

The only other local municipalities that have conducted awareness on the risks of dolomite and sinkholes are the City of Tshwane Metropolitan Municipality and Ekurhuleni Metropolitan Municipality (EMM). The EMM distributed awareness leaflets designed for this purpose and awareness billboards have been erected. The lack of a comprehensive risk awareness strategy or risk awareness plan with robust community consultation as part of the DRMS leaves a gap.

The TCC made the decision to take a pro-active approach to dolomite risk management and awareness by including awareness actions in all the respective phases and to specify the DRCS in detail as part of the DRMS. In each of the phases of the TCC DRMS, the risk was mitigated by creating awareness and acknowledging the lessons of the past. The following phases form part of the TCC DRMS:

- Phase A

  The Initial Geo-Environmental Assessment of Dolomitic Land (2009 to 2010) was completed in 2010 and resulted in the development of a knowledge base, GIS database, and technical report from which a framework was developed to implement a long-term DRMPr.

- Phase B

  Implementation of the initial DRMP (2010 to 2013) comprising of a combination of detailed research, risk analysis and evaluation actions to quantify the risk of dolomite, the management of risks, small scale mitigation of known risks, as well as establishing a comprehensive risk monitoring programme.

- Phase C

  The long-term risk management, mitigation, monitoring and review phase (ongoing on an interim basis from 2011) focuses on the implementation of mitigation measures on a long-term basis, as well as managing and monitoring the risk as defined by the updated DRMP.

5.5 DRMS Phase A

The Preliminary Geo-Environmental Assessment of Dolomite Land in Potchefstroom (AGES, 2010a) assigned priority risk ratings to areas based on the risk levels and status of infrastructure in this area. These risk ratings referred to the probability that dolomite and sinkholes might occur

on failed wet infrastructure and was organised into focus areas. Research and mitigation could then concentrate on these areas (AGES, 2010a; Pretorius, 2012a:21). In a low-cost housing area such as the affected areas of Ikageng, this would certainly be a highly probable scenario. During the Regional Dolomite Assessment (AGES, 2010b; Pretorius, 2012a:25), existing information was collated from sources such as regional mapping and regional risk determination.

5.5.1 DRMS Phase A: DSI research processes

During Phase A of the DRMS, a DSI is conducted as part of the research. The following actions form part of the Phase A, DSI preliminary geo-environmental assessment:

- Existing information and data are collated
- Regional mapping
- Regional risk determination
- Indicated risk map
- DRMS framework and DSI framework.

5.5.2 The foundation for a risk awareness plan

The TCC approved the DRMS and DRMPr in July 2010 (C120/2010-06-09), but a year-long delay due to political instability halted the implementation of these reports. The occurrence of subsurface events and hazardous activities on high risk dolomite necessitated a strategic planner (AGES, 2011) to define the risks to the TCC and residents.

One of the four key recommendations made focused on a DRCS (AGES, 2011; Tlokwe City Council, 2011b). The most significant recommendation resulting from this report was the establishment of a Dolomite Steering Committee (DSC), tasked to assist the TCC with all technical implementations and legal issues, as well as the implementation of dolomite risk awareness actions (MM Resolution 163/2011-11-22).

5.5.3 Who are the stakeholders?

Tasked with instituting an awareness plan, the DSC requested that all stakeholders be identified so that they could be included in awareness actions. Figure 5-2 represents the framework for the identification of stakeholders. They are important as the policy and funding decisions come from some tiers of stakeholders, others represent the affected communities themselves, the municipality that has to support the project and the contractors and decision makers who has to implement the strategy.

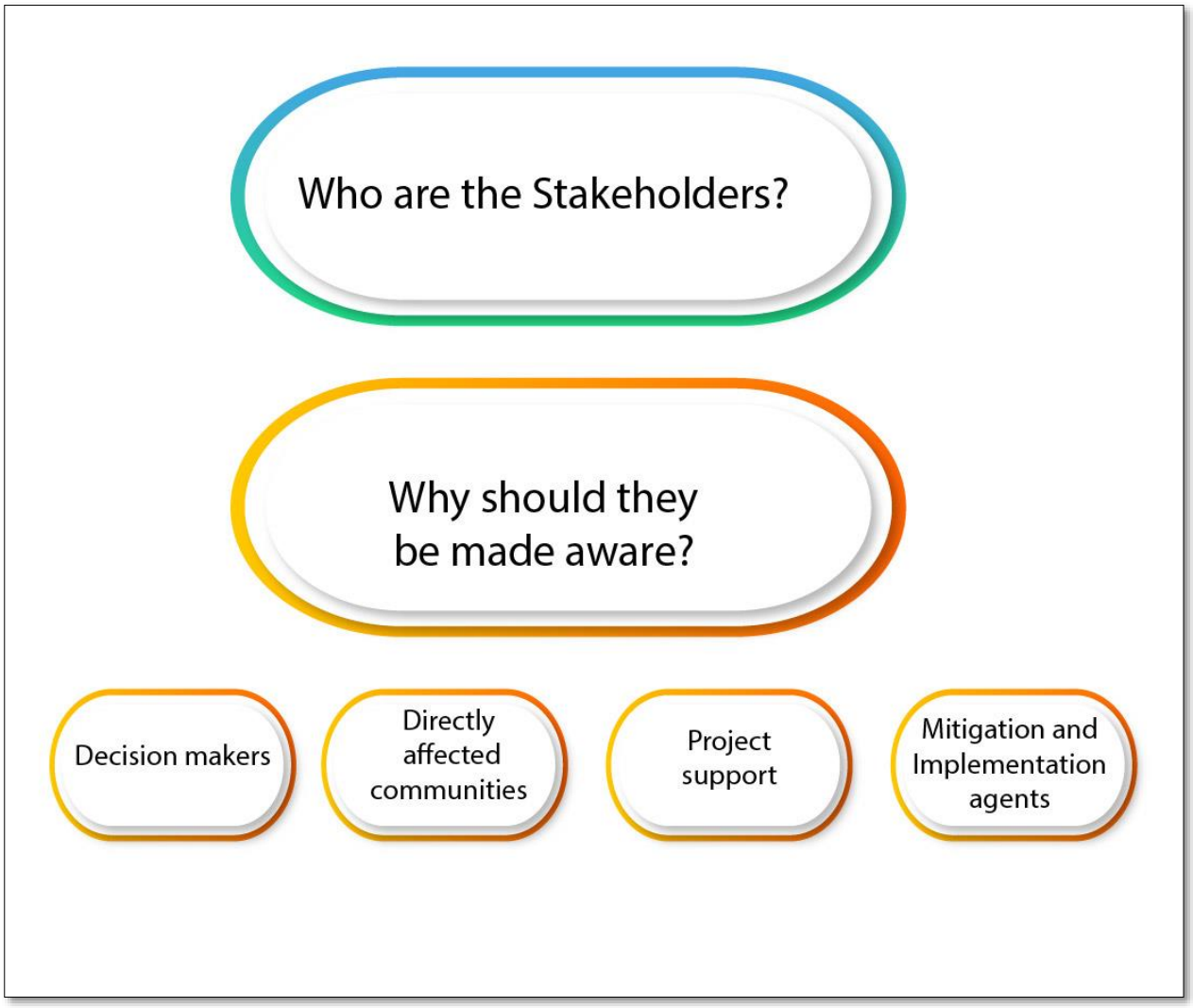


Figure 5-2: Stakeholder identification

5.6 Engagement of stakeholders as part of the Tlokwe DRMS

5.6.1 Imperative to create dolomite risk awareness among affected communities in TCC

The affected community has the right to know to which risks they are being exposed. Public participation can contribute towards reducing the probability of events occurring in low-cost housing areas, making it critical to educate the community on monitoring and vigilance (Buttrick & Roux, 1993; Buskirk *et al.*, 1999; Gutiérrez *et al.*, 2007). Morgan *et al.* (2002:7) postulate that during and following research, technical specialists and scientists are often not communicative about the hazards and associated risk to affected stakeholders, which leads to loss of credibility of the scientific process and purveyors thereof.

Walker *et al.* (2008:648) define stakeholders as individuals or groupings who have an interest in or proprietorship of the project, or people who could be affected by it or contribute toward it.

Stakeholders can also be described as any group or person that may exert influence on a project or who may be influenced by it (Freeman, 1983; Freeman, 2010). For this study, the definition was as broad and encompassing as possible. Throughout the respective phases of the implementation of the DRMS, the stakeholder definitions were consolidated into focused and prioritised interest and influence groupings.

The communication of risk to stakeholders requires time and resources (Sen, 2000; Lundgren & McMakin, 2013), which are limited commodities in most governmental projects. Walaski (2011:8,9) supports the notion that communicating risk to stakeholders is an ongoing process and therefore time consuming. Walaski (2011:9) also accentuates the complex process of convincing the decision makers of the necessity of stakeholder engagement and the allocation of resources toward this goal during the process of mitigation of anthropogenic factors. Morgan *et al.* (2002:2) indicate that the dissemination of information regarding the anthropogenic risks assists stakeholders in deciding which risks warrant their limited time, attention and resources and address the specific characteristics of a low-cost development. The awareness plan informs them as to the nature of the hazard, how the risk can be managed and how they can contribute through vigilance and mitigation measures.

Walaski (2011:36) refers to relationship development, information sharing and reaching consensus as key approaches to engaging stakeholders. These approaches also served as the foundation for the engagement of stakeholders within the DRCS.

Internal and external stakeholders had to be identified and analysed (Walaski, 2011:71) to establish whether all possible affected and tangential stakeholders have been included. This compilation of stakeholders was mapped according to interest in the project and levels of involvement (Murray-Webster & Simon, 2006; AGES, 2016a).

The risk awareness measures that are implemented not only serve as powerful instruments in mitigating anthropogenic factors, but the participation of communities in actions that affect their very existence are required by law.

5.6.2 Legal framework for engaging dolomite-affected stakeholders

Public participation and the involvement of affected stakeholders are governed by fundamental source legislation. The guidelines, acts and standards that apply to communities and local governance underlain by dolomite are the following:

- Constitution of South Africa (Act 108 of 1996),
- Geoscience Amendment Act, 16 of 2010.

- Department of Mineral Resources and Geoscience Amendment Act Regulations, 16 of 2010.
- Department of Mineral Resources. Governmental Notice, 7 September 2011.
- South African National Standard SANS 1936 Parts 1–4.
- Consultants' guide for the approach to sites on dolomite land by the TCC for Geoscience (2007).
- South African Institute of Engineering and Environmental Geologists (2003) Guideline for engineering, Geological characterisation and development of dolomitic land. Council for Geoscience.
- Department of Public Works, 2010. Appropriate development of infrastructure on dolomite: Manual for consultants.
- Building Regulations and Building Standards Act, 103 of 1977
- South African National Standard SANS 633: 2009 – Edition 1 (in Draft).
- GFSH-2 Guidelines of the National Department of Housing (2002).
- National Home Builders Registration Council. 1999. Home Building Manual Part 1 & 2. Revision No: 1. February 1999.
- Housing Consumers Protection Measures Act, 95 of 1998, section 12
- South African National Standard SANS 10400-B and H, as indicated in the Building Regulations and Building Standards Act, 103 of 1977.
- National Building Regulations and its amendments from 2008 (Act 103 of 1977).
- Disaster Management Act, 57 of 2002.
- Occupational Health and Safety Act, 85 of 1993
- National Environmental Management Act, 107 of 1998.
- National Water Act, 36 of 1998.
- National Environmental Management Waste Act, 9 of 2008
- Spatial Planning and Land Use Management Act, 16 of 2013.
- The right of the public to be informed about the risk of dolomite according to the Promotion of Access to Information Act, 2 of 2000.
- Various municipal by-laws (AGES, 2013c)

The legislative, policy and constitutional requirements in key sources regarding development on dolomitic land and public participation were considered for the design of the DRCS. They can be summarised as follows:

The idea or concept of public participation in government is established in the Constitution of South Africa, 1996. Chapter 2 of the Constitution contains the Bill of Rights, which includes equality, human dignity, freedom, environment, as well as the right to housing, health care, food,

water, social security, education and access to information.

The White Paper on Local Government 1998 (South Africa, 1998b) recommends that municipalities ought to develop mechanisms to ensure citizen participation in policy initiation and formulation, and the monitoring and evaluation of decision-making and implementation. The following approaches can assist to achieve this:

- Forums to allow organised formations to initiate policies and/or influence policy formulation, as well as participate in monitoring and evaluation;
- structured stakeholder involvement in certain council committees, in particular if these are issue-oriented committees with a limited lifespan rather than permanent structures;
- participatory budgeting initiatives aimed at linking community priorities to capital investment programmes; and
- focus group participatory action research conducted in partnership with NGOs can generate detailed information about a wide range of specific needs and values.

The Municipal Structures Act, 117 of 1998 (South Africa, 1998a) as amended, allows for a Category A municipality with a sub-council or ward participatory system, or a Category B municipality with a ward participatory system, and executive committees or an executive mayor to annually report on the involvement of communities and community organisations in the affairs of the municipality. Section 72 states that the objective of a ward committee is to augment participatory democracy in local government and in section 74 deals with the functions and powers of ward committees.

The Municipal Systems Act of 2000 (South Africa, 2000) defines “the legal nature of a municipality as including the local community within the municipal area, working in partnerships with the municipality’s political and administrative structures…to provide for community participation”.

According to the Municipal Systems Act of 2000, section 4 (c) (e) (South Africa, 2000), the council has the duty to:

- encourage the involvement of the local community;

- consult the community about the level quality, range and impact of municipal services provided by the municipality, either directly or through another service provider.

The Municipal Systems Act of 2000, section16 (1):

- Encourage and create conditions for the community to participate in the affairs of the

municipality, including in the IDP[13], performance management system, monitoring and review of performance…preparation of the budget, strategic decisions regarding municipal services

- Contribute to building the capacity of the local community to participate in the affairs of the municipality and councillors and staff to foster community participation.

The TCC bylaw pertaining to public participation is discussed later in this chapter.

SANS[14] 1936 (2012b) regulates the development and implementation of a DRMPr. The TCC has complied with this requirement and subsequently re-affirmed their commitment to affected communities and to acting pro-actively by issuing council resolutions to legitimise the DRMS, hereby making all actions recommended in the DRMS enforceable (Tlokwe City Council, 2009; Tlokwe City Council, 2010; Tlokwe City Council, 2011a; Tlokwe City Council, 2011b; Tlokwe City Council, 2012; Tlokwe City Council, 2013; Tlokwe City Council, 2014a; Tlokwe City Council, 2014b). The awareness actions and engagement of all stakeholders formed part of these recommendations.

5.6.3 Levels of engagement of stakeholders

The levels of engagement applied in the TCC case study refer to the guidelines of the International Association for Public Participation (2000). The levels of engagement are presented as a spectrum of participation starting from the lowest levels of engagement and progressing to the ideal state of participation. These levels are summarised in Figure 5-3. In the South African context, the most highly functioning level, namely empowerment, may not be realised easily, as not all stakeholders will be granted autonomous decision-making powers within our legal framework (Du Toit & Pollard, 2008:709).

Some of the levels of engagement, such as providing information, are associated with one-way communication, but when implemented within a participatory framework as the objective is with the DRCS, even the provision of information can take place within a context of sharing, listening and responding to questions. When stakeholders are manipulated or placated to accept the actions associated with a project, stakeholder engagement serves as non-participation.

[13] Integrated Development Plan is the principal strategic planning instrument that informs all planning and management for local government.

[14] South African National Standards.

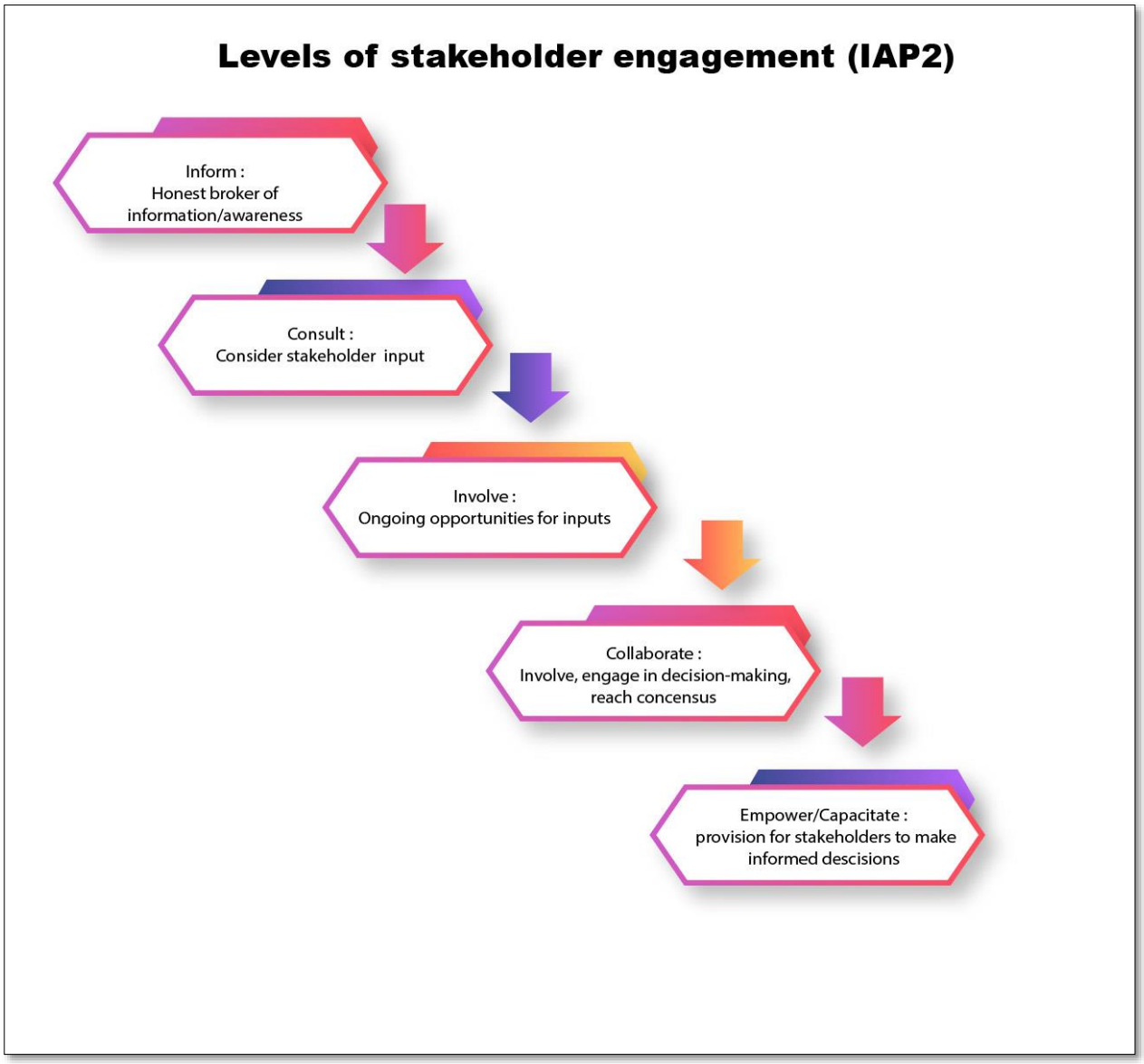


Figure 5-3: Levels of stakeholder engagement based on IAP2 (International Association for Public Participation, 2000).

5.6.4 Objectives of communicating the risk to stakeholders

Now that the different stakeholder groupings and their aim have been explained the timing of communicating the risk has to be decided. Considering the urgency of communicating the risk associated with dolomite in TCC to affected residents, the objectives of the DRCS were the following:

- Communicating the risk directly to affected residents and establishing communication channels;

- communicating roles and responsibilities of consultants and the TCC in the DRMPr;
- establishment of regular transparent communication to residents affected by dolomite;
- stakeholder ownership of dolomite risk in order to mitigate the risk in a sustainable way;
- proactive approach to consultation with stakeholders;
- equipping key stakeholders within the affected communities so that they can equip others; and
- establishing trust in the TCC and service providers to the TCC to mitigate the risk (AGES, 2016a).

The chosen actions had to effectively disclose and share information concerning the dolomite hazard and the outcomes of research conducted. As is often the case, some stakeholders, such as politicians, felt excluded and felt that information was lacking. Addressing these issues was critical in maintaining stakeholder engagement and transparency, therefore grievances were addressed through the media, political, governmental and other channels proposed in the DRCS (AGES, 2016a).

5.6.5 Stakeholder identification and mapping

Glicken (2000:307) argues that "stakeholders" can be considered a relative term, as communities, the public and groupings only become stakeholders in reference to a specific issue or risk affecting them directly or indirectly.

The mapping of stakeholders into tiers not only aligned awareness methods, but also appropriate levels of engagement with the nature and register of stakeholder groupings. Deciding on the positions and priorities of stakeholder groupings or individual stakeholders is only of limited value if they are not actively engaged in practice (Murray-Webster & Simon, 2006:2). Murray-Webster and Simon (2006:2) suppose that only communication plans that are informed by accurate and complete stakeholder mapping and analysis can be effective.

The process of identifying and mapping stakeholders does not constitute stakeholder analysis as yet. Murray-Webster and Simon (2006:3) are of the opinion that when stakeholders are engaged and motives and positions concerning the project are established, the process of stakeholder analysis has begun. Provisional analysis could be done on the basis of what was known publicly about the viewpoints, intentions and motives of affected stakeholders, but this could only be authenticated after the initial engagement actions and evolved throughout the life cycle of the DRMS. This is critical where stakeholders such as the residents living in low-cost housing developments or settlements are concerned, as their attributes may differ from other more permanent or privately constructed homes in residential areas. The tendency of motives evolving and the propensity of stakeholders to change stances and re-group to associate with alternative

groups is discussed later in this chapter.

Reed (2008:2421) proposes that the toolkit approach, which is based on the premise of selecting the most suitable stakeholder tools and that was traditionally utilised in stakeholder mapping and analysis, should be substituted by a process approach. The identification of stakeholders should be regarded as an iterative process (Reed, 2008:2421; Reed *et al.*, 2009:1937) where stakeholders are added as the project progresses.

In deciding who the stakeholders were, this research commenced with the requirements of the SANS 1936 (2012b), which specifies that dolomite risk management shall be implemented at four levels, as illustrated in Figure 5-4.



Figure 5-4: DRM levels (SANS, 2012a) (Own representation)

In order to implement the management of dolomite risk at each level, the stakeholders would have to be engaged in such a way that the risk can be understood and they comprehend the motivation

behind requirements for developing and living in dolomitic areas (SANS, 2012b; AGES, 2016a). These levels have been taken as broad guidelines as to who the stakeholders for this complex issue were. From this point of departure, the following questions were formulated:

- Considering the relevant legislation, who should be engaged?
- After the risk has been quantified, who is most at risk?
- Who needs to be engaged as partners in managing the risk?

The focus should not merely be on compliance with legislation and guidelines, but also on learning, equity, trust creation and equipping stakeholders (Reed, 2008:2422). In South Africa there is an added dimension of redressing the wrongs of the past. There are stakeholder groupings such as displaced communities that are more vulnerable due to Apartheid legislation and inequality. The residents of low-cost housing are the stakeholders most affected by social injustice. They were specifically prioritised and empowered to create resilience through the process of engagement, thereby mitigating the risk of anthropogenic factors in high risk dolomitic areas.

5.6.5.1 District and local municipalities

The inclusion of all municipal departments, officials, council members and decision-making structures formed the basis of all other actions concerning dolomite (Morgan *et al.*, 2002:35; Walaski, 2011:46). There had to be a seamless link between all stakeholders involved in order to manage the risk to council and residents. The starting point of the creation of awareness was the percipience of what dolomite is, the dissemination of research findings, and the recognition of the risks associated with living on dolomite. Mutual understanding and trust when managing dolomite and implementing the DRMS depend on informed and engaged stakeholders.

5.6.5.2 Government departments and organs of state

Government departments were included, as they are the source of support for the management of dolomite, thus enhancing the regional and national management of dolomite. They are the prime purveyors of the mitigation of anthropogenic factors as they are also most involved in the development of low-cost housing and the infrastructure associated with these developments.

5.6.5.3 Directly affected communities

The communities affected by dolomite exhibited extreme variations in risk awareness levels, ranging from having no knowledge of dolomite or the potential associated risk, while others were well informed about dolomite and the effects it may have on them. There were residents who had already witnessed sinkholes. Inaccurate narratives concerning dolomite already existed, and they

were in many instances politically motivated (AGES, 2012). The levels of awareness, as well as narratives concerning dolomite and sinkholes, was taken into consideration on a strategic level when considering the affected community as stakeholders.

It was of critical importance to include all representatives of the community and the community at large. Plans were devised to include all interested stakeholders, affected stakeholders, decision-making partners in business and government, as well as the general public in order to voice and hear each other's fears and concerns and become part of acceptable risk management decisions (Morgan *et al.*, 2002:9). The exclusion of stakeholders at this early stage may have led to difficulties in communicating and mitigating the risk as part of the implementation of the DRMS throughout the project life cycle. Including as many stakeholders as possible not only aids the successful implementation of a DRMS, but empowers the affected community and gives a voice to their fears concerning their future, especially when they are vulnerable such as residents of low-cost housing.

As stakeholder engagement levels may not correspond to the capacity or resilience of the stakeholders, Sen (2000:90) recommends that proxy organisations such as non-governmental organisations (NGOs) and community forums that represent communities are involved. Stakeholder groupings from the affected communities included leaders from various forums and structures representing the community formally and informally:

- ward councillors
- ward committees
- church leaders
- local media
- non-governmental organisations
- labour movements
- local business structures
- political structures
- educational institutions

5.6.5.4 Service providers

Service providers that deliver services to municipal departments that are directly affected by the risk associated with dolomite had to be included as it was critical that they receive accurate technical information on how to mitigate the risk associated with dolomite in their fields of expertise. The contractors that are involved in the construction of low-cost housing developments

were a specific target for DRCS.

Planners, architects and draughtsmen should be aware of the design and building requirements for the different dolomite zones. Engineers, infrastructure and building contractors and other service providers should be aware of the technical requirements for development on dolomite. The omission of any of these stakeholders increases the risk of anthropogenic factors to residents, the municipality, and service providers as such, and hinders the mitigation of risk on dolomite.

5.6.5.5 External stakeholders

The politicising of the dolomite issue elevated the focus on communication of the occurrence and the associated risk of dolomite with external stakeholders. The expectation at the beginning of the DRC campaigns was that narratives employed by proponents of opposing political views or activists may be neutralised when stakeholders are empowered with an understanding of dolomite and how they can contribute to the mitigation of anthropogenic factors and its associated risk. This would then aid the acceptance and understanding of the motivation behind the preferential resettling of households underlain by dolomite on new erven[15] while others had been on waiting lists for many years. This stakeholder grouping will later be the focus of difficulties with what seemed to be a matter of *knowledge is power,* but it was in fact not that simple.

5.6.6 Stakeholder maps

The preliminary stakeholder maps were compiled by means of various work sessions in which the interdisciplinary team contributed from their fields of experience and identified stakeholders interacted with their various disciplines. These work sessions were conducted keeping in mind that participatory processes lead to sustainable and high-quality involvement of stakeholders (Gariépy, 1991; Chess & Purcell, 1999; Reed, 2008). Considering the commitment of the project to sustainable and high-quality outcomes, the participatory approach was employed throughout the different DRMS phases. The stakeholder maps were defined and compiled by me as coordinator of all awareness actions.

Stakeholders identified during the initial work sessions were invited to participate in a stakeholder workshop (AGES, 2013d) where they were provided with the relevant background to the project. They then contributed suggestions on which stakeholders they felt should be consulted and made recommendations about the levels of participation for each stakeholder definition. The objective was only to provide a point of departure from where the awareness campaign could be planned

[15] Erven is a South African term that refers to a plot of land demarcated for building purposes.

and implemented in a meaningful way.

The levels of engagement and associated actions at each level fluctuated and were adapted as the phases of the DRMS were implemented. The awareness plan was adjusted and moulded by me around the technical research and stakeholder response and input, constituting an iterative process grounded in the response of the stakeholders to interventions.

A preliminary stakeholder analysis was compiled (Pretorius, 2012b) and the focus fixed on empowering the TCC as decision makers with an essential understanding of dolomite and sinkhole formation, as well as its legal implication through various presentations to council. The approach of the project was the focus on the community as end-user of geotechnical, engineering and environmental interventions and with this the mitigation of anthropogenic risk was pivotal. This stance informed the TCC council resolutions, which focus on the establishment of dolomite risk awareness. During this period, the first focus groups were facilitated by me with institutional and community leaders from the affected low-cost developments on dolomitic areas.

Fischhoff (1995:138) declares that risk communication begins before a word is spoken on the subject. The fact that the risk is not communicated sets the tone for the trust relationship to follow. Even the perception that there is an unwillingness to share information creates mistrust, as will be confirmed later in the study. The TCC therefore made the decision to create awareness from the inception of the research process. The focus group discussion facilitated by myself during the project conclusion illustrated that a perception of unwillingness to communicate may indeed damage the overall efforts of mitigating the anthropogenic risks.

5.6.7 Vulnerable stakeholders

Together with the TCC, the residents directly affected by dolomite in the TCC jurisdiction were the main stakeholders who had to be engaged in dolomite risk awareness actions. The vulnerability of a community influences the methods and levels of engagement of risk awareness actions. Therefore, a study was done to ascertain the levels of vulnerability by assessing existing data. In this thesis I will be retaining the term “vulnerability”, although other options may be considered, such as resource-constrained (Koekemoer, 2018:14; Khumalo, 2019:36), but my perception is that it does not include all the dimensions the term “vulnerability” encompasses. The difficulty with the term vulnerability is that it is socially constructed. Most definitions are degrading and seems to focus on character flaws and diminished autonomy (Silva, 1995:15; Moore & Miller, 1999:1034; Liamputtong, 2007:2).

Vulnerable is derived from the Latin noun *vulnus* ("wound"). "*Vulnu*s" led to the verb *vulnerare,* meaning "to wound." "Vulnerable" originally meant "capable of being physically wounded" and it

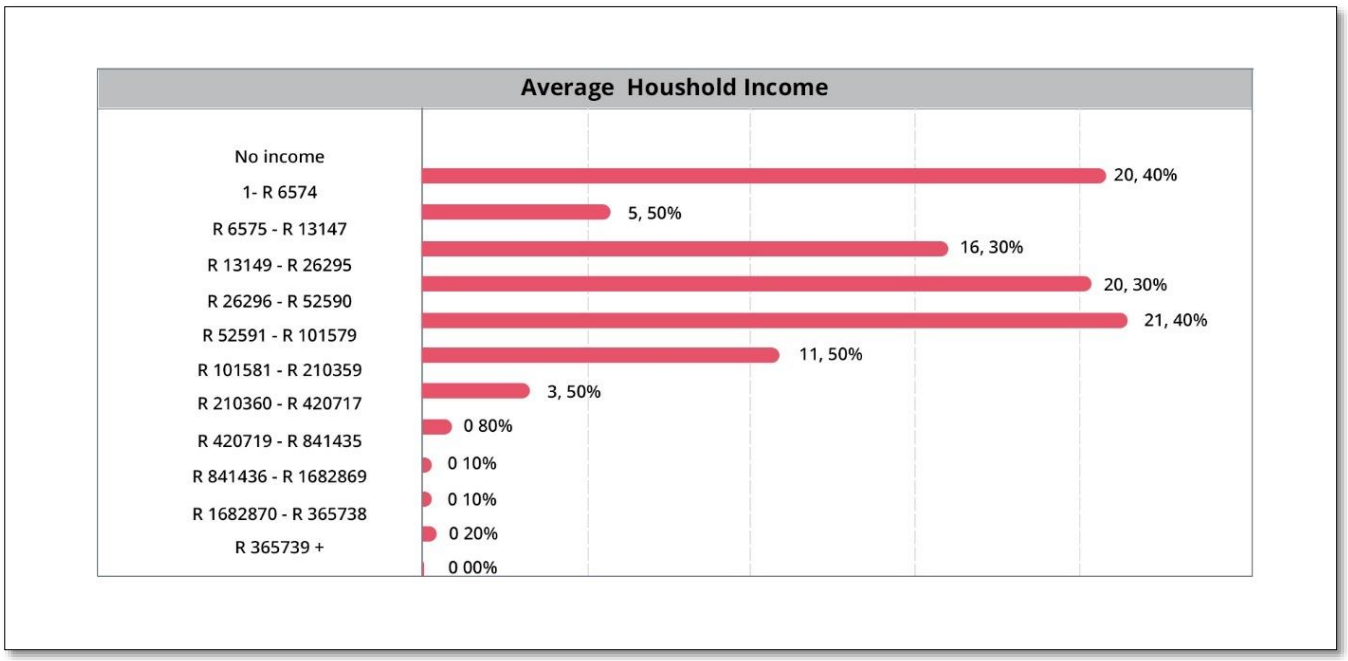
is also used figuratively to suggest a lack of power against non-physical abuse. In other words, someone (or something) can be vulnerable to criticism or failure as well as to literal wounding. Nyamathi (1998:65); Punch (2002:323) focus on the impoverishment, disenfranchisement, increased susceptibility to adverse outcomes, discrimination against, and susceptibility to coercive or undue influence of vulnerable groups. This is a better fit for how I perceive vulnerability in communities.

This thesis identified two broad categories of stakeholder vulnerability:

- General vulnerability due to political and socio-economic reasons; and
- vulnerability in terms of the anthropogenic factors that increase the risk of living on dolomite.

5.6.7.1 General vulnerability

The Economic Area Analysis of the Tlokwe Neighbourhood Development Partnership Grant (NDPG)[16] (DEMACON, 2013:18) shows the vulnerability of this community using three basic indicators: average household income (Fig.5-5), levels of education (Fig. 5-6) and unemployment levels (Fig. 5-7).



[16] The purpose of the grant is to fund, support and facilitate the planning and development of neighbourhood development programmes and projects that will be catalysts for further development in these areas. It is managed by the National Treasury.

Figure 5-5: Average household income TCC (Demacon, 2013)

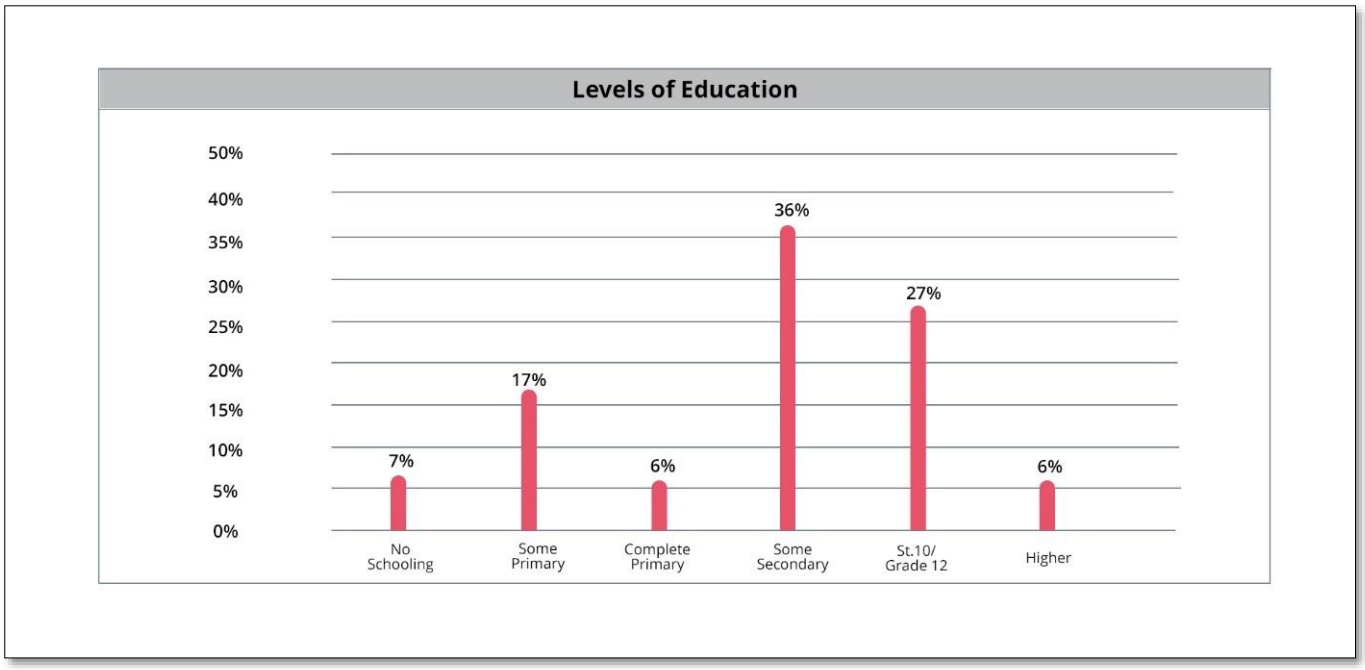


Figure 5-6: Levels of education TCC (Demacon, 2013)

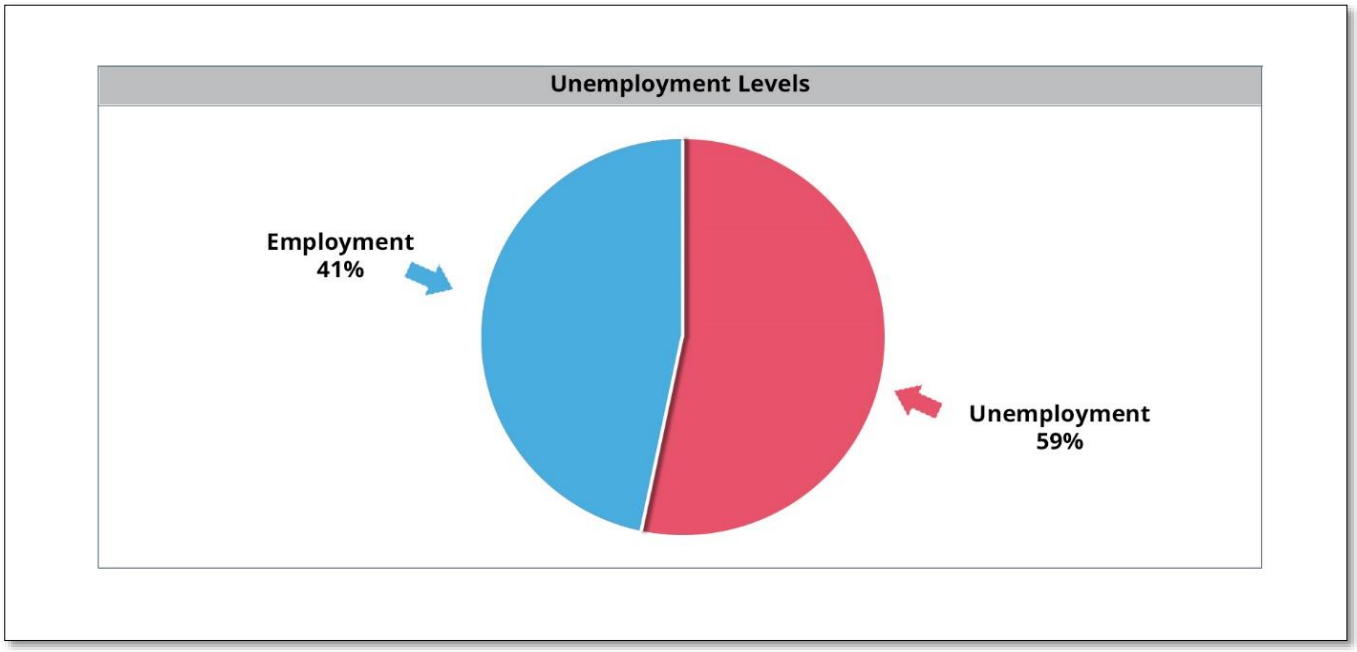


Figure 5-7: Unemployment levels TCC (Demacon, 2013)

When planning dolomite risk awareness actions, the vulnerability of affected stakeholders can be reduced by considering current narratives, literacy levels and educational levels. These actions must reflect the basic tenets of transparency and access to information in order to create trust

and decrease fear.

The capacity to control the exposure to the dolomite risk will greatly reduce the vulnerability of the affected communities. This can be done by empowering communities with technical knowledge and giving them responsibilities to monitor for signs of dolomite instability and sinkhole formation.

5.6.7.2 Vulnerability to the anthropogenic risk of living on dolomite

It is precisely due to general vulnerability that residents have no choice but to resort to these manifestations of housing. Further assessment shows the extent of low-cost housing on very high-risk dolomite. Table 5-1 illustrates the housing categories exposed to different risk zonation.

Table 5-1: Residents affected (AGES, 2013d)

Residents affected							
Dolomite Risk Management Area	Existing Stands	Stand Population	Backyard Dwellers on stand	Backyard Population	Illegal Informal Structures not on Stand	Illegal Squatters Population	Total Residents Affected
DRMA1	1890	6549	368	810	593	2016	**9375**
DRMA2	275	1069	72	142	108	367	**1578**
DRMA3a	1707	6490	192	390	53	180	**8515**
DRMA3b	392	1301	69	154			
DRMA4	1011	3746	150	314	5	17	**4077**
DRMA5	418	87	1	1	88	299	**387**
Totals	**5693**	**19242**	**852**	**1811**	**847**	**2880**	23933

Zoning in Table 5-2 shows the incidence of community-related activities on dolomite, which invariable accompanies low-cost housing developments. The occurrence of schools and churches on dolomite further complicates adherence to anthropogenic mitigation and renders residents even more vulnerable.

Vulnerability also points to the vulnerability of a community to the dolomitic hazard, and to the anthropogenic factors that influence the risk posed by dolomite. Some stakeholder groupings will be more vulnerable than others because of the poor structural quality of their homes or ignorance about the effects of non-compliance to building regulations. Dolomite risk awareness actions

should consider this vulnerability by acting promptly and providing as much information as possible for them to reduce some of the vulnerability to anthropogenic factors.

Table 5-2 :Community-related activities on dolomite (AGES, 2013d)

Community related activities and land use on Dolomite							
No	**Facility Type**	**Name**	**Town**	**No**	**Facility Type**	**Name**	**Town**
1	Educational	Creche	Ikageng	23	Religious	Church	Ikageng
2	Educational	Pudulogo Primary School	Ikageng	24	Religious	Church	Ikageng
3	Educational	Bolitirelo Primary School	Ikageng	25	Religious	Church	Ikageng
4	Educational	Tshepo Primary School	Ikageng	26	Religious	Church	Ikageng
5	Educational	Resolofetse Secondary School	Ikageng	27	Religious	Church	Ikageng
6	Educational	Boitshoko Secondary School	Ikageng	28	Religious	Church	Ikageng
7	Educational	Promosa Secondary School	Promosa	29	Religious	Church	Ikageng
8	Sport and Recreation	Municipal Swimming Pool	Mohadin	30	Religious	Church	Ikageng
9	Sport and Recreation	Clubhouse and Tennis Courts	Mohadin	31	Religious	Church	Ikageng
10	Community Facility	Mohadin Community Centre	Mohadin	32	Religious	Church	Ikageng
11	Community Facility	Mohadin Library	Mohadin	33	Religious	Church	Ikageng
12	Clinic	Ikageng Clinic Ext 4	Ikangeng	34	Religious	Church	Ikageng
13	Clinic	Mamerotse Clinic	Mohadin	35	Religious	Church	Ikageng
14	Cemetery	Lusaka Cemetery	Mohadin	36	Religious	Church	Ikageng
15	Cemetery	Ikageng Cemetery	Ikangeng	37	Religious	Church	Ikageng
16	Taxi Rank	Sarafina Rank (Informal)	Ikangeng	38	Religious	Church	Ikageng
17	Taxi Rank	Lusaka/Kanana Rank (Informal)	Ikangeng	39	Religious	Church	Ikageng
18	Taxi Rank	Ikangeng Rank (Informal)	Ikangeng	40	Religious	Church	Ikageng
19	Taxi Rank	Mohadin Rank (Informal)	Ikangeng	41	Religious	Church	Mohadin
20	Religious	Church	Ikangeng	42	Religious	Church	Promosa
21	Religious	Church	Ikangeng	43	Religious	Church	Promosa
22	Religious	Church	Ikangeng	44	Religious	Church	Promosa

5.6.8 Sarafina subsidence event

On the 16th of May 2011, the first sinkhole within a built area of Potchefstroom was reported and the area was prioritised. The Sarafina subsidence event triggered a DSI for this focus area in Ikageng to determine the risk to residents and council infrastructure (Pretorius, 2012a:31). The incident created stirrings in a community who had up to then been oblivious of the impending risk and felt relatively safe. This necessitated that the risk awareness actions be prioritised.

5.6.9 Institutional awareness

The primary actions as part of creating awareness, other than with the council members, was the Dolomite Risk Management workshop that included pivotal officials from all departments in the TCC. A presentation was given and awareness material distributed to officials. During the preparation for workshops, the significance of relevant and communicative knowledge material became apparent. Residents and officials indicated that they did not believe that there was dolomite as they could see nothing on the surface. The need existed to visually represent subsurface karst. The only available pamphlet that could be found during personal and internet searches on dolomite and sinkholes was not considered relevant or of adequate standard to use for any of the stakeholder groupings. During Phase B awareness leaflets were developed in response to this gap.

5.7 DRMS Phase B

One of the objectives of engaging residents and awareness actions is to help the residents take ownership of the reality and mitigation of risk through the mitigation of anthropogenic factors (AGES, 2016a). This entailed that stakeholders either had direct personal control over the risks or indirect control by means of influence such as enforcing policies and legislation or the management of hazards (Morgan *et al.*, 2002:2). Elaborating on this, Morgan *et al.* (2002:22) indicate that emotional and cognitive skills are needed to receive and understand the risk awareness information supplied, but that the affected communities will still be vulnerable if the information contained in the risk communication is not accurate and inclusive. This conclusion supports the concept of aggregating a scientific information and data framework as foundation for awareness actions. There has been criticism on the exclusive use of a scientific model (Morgan *et al.*, 2002:4; Reynolds & W. Seeger, 2005:48; Reynolds, 2011). Reynolds (2011) promotes the idea of an integrative model, and Morgan *et al.* (2002:4) propose a mental model approach. The mental model approach complements the scientific framework with the beliefs and concerns of the affected stakeholders (Fischhoff, 1995:9). The risk communication actions are then designed to address the tenets of this framework.

Walker *et al.* (2008:648) reason that what we perceive as facts are merely our interpretation of intricate ideas. They are constructed perspectives within our own social framework. We choose these facts to represent the reality of the risk, but to other stakeholders our representation may seem biased, misrepresented or vague. Knowing what the affected communities should know is just one dimension of risk communication (Cone *et al.*, 2013:351). Their perceptions, narratives and indigenous knowledge concerning dolomite and sinkholes completed the picture.

During Phase A, the scientific information was gathered, and the data framework was developed by the interdisciplinary team. This framework was then collated by social scientists under my guidance to match the responses to the most pressing concerns from the side of the community. These concerns were isolated by means of the first focus group workshop held during DRMS Phase A where the stakeholders were identified and community leaders could provide input as to the most crucial issues surrounding the concerns and uncertainties about the management of the dolomite and sinkhole risk (AGES, 2012).

The issues isolated in conjunction with the essential scientific information and social practice were consolidated to form the Integrative Risk Awareness Framework (Fig. 5-8) that formed the knowledge base for all risk awareness tools and awareness processes in the DRCS.

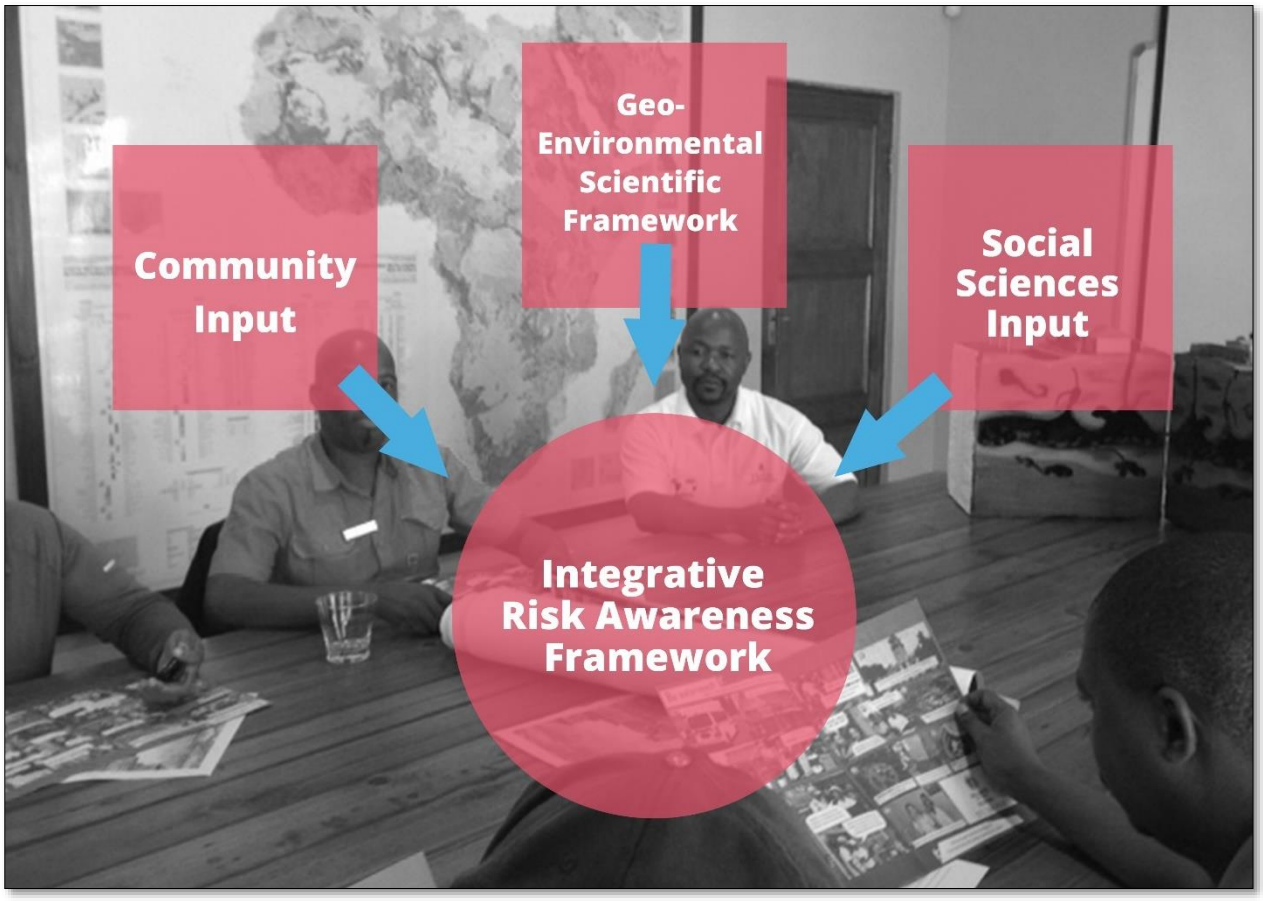


Figure 5-8: Integrative Risk Awareness Framework

Morgan *et al.* (2002:21) assert that risk communication should begin by stating the myths concerning a specific disaster risk and then correcting it. In this study, I found that openly stating the incorrect narratives created confusion. Feedback from focus groups that were held throughout the different phases as feedback instruments indicated that especially vulnerable groups incorporate the incorrect narratives as factual elements.

Since the technical specialists were not trained to engage stakeholders and found it frustrating (Morgan *et al.*, 2002:7), the technical team decided from the start of the research in Phase A to assign the principal responsibility of engaging stakeholders to social scientists and in this case primarily me, within an interdisciplinary team of technical specialists and representatives from the TCC.

5.7.1 Phase B: DSI research processes and outcomes

Following another delay of seven months due to political instability, the Phase B study was approved by the TCC (Council Resolution C145/2013-07-02). The research processes required

for Phase B DSI acted as “building blocks and not steppingstones” (Pretorius, 2016). Each action provided data for the next actions, with the DRMP and DRMS as the cumulative result of these actions.

During Phase A of the DRMS, the TCC drafted a resolution (C145/2013-07-02), which stated

“That a community awareness and information strategy be implemented with immediate effect”.

This TCC resolution not only triggered the initial awareness planning and interventions, but also the compilation of a social awareness framework in phase B of the DRMS. The urgency of the situation created by the Sarafina incident necessitated the immediate launch of key actions while developing the framework.

The approach I took was to match the awareness actions and stakeholder groupings with the technical research actions. The principle of a phased approach originated from research conducted by Aucamp (2003). This alignment of social actions within the project life cycle inspired the idea of matching social awareness actions with the technical phases in the DRMS life cycle.

The residents living on dolomite represented an overburden of vulnerable people. It was therefore essential to adhere to all legislation regarding the dissemination of information in order to empower vulnerable communities to mitigate the anthropogenic risk. When the minimum requirements of public participation and awareness requirements as stated in the Tlokwe bylaws had been met, the rest of the framework could be addressed with creative and innovative approaches to creating risk awareness. The very specific Tlokwe Public Participation bylaw was helpful as a foundation for the awareness framework.

The Tlokwe Public Participation bylaws focus on public participation processes when lodging complaints concerning governance and the IDP, but they can be applied to all communication emanating from the TCC. For this purpose, bylaw *5.7: Notification* and *8. Communications to local communities* had to be perused (Tlokwe City Council, 2004).

Bylaw 5.7: Notification

5.7.1 *Whenever the Council -*

5.7.1.1 holds a public meeting as provided for under this bylaw;

5.7.1.2 holds a session about any matter contemplated in subsection 5.3; or

5.7.1.3 holds a public meeting on any other matter decided by the Council that warrants notification to the community; the aforesaid matters must be advertised once in two of the daily

newspapers as well as community newspapers circulating in the municipal area according to the Council's language policy for a period of at least fourteen (14) days before the event.

5.7.2 Copies of all notices contemplated in subsection 5.7.1 must be posted at -

5.7.2.1 the noticeboard at the Council's offices;

5.7.2.2 all libraries in the municipal area; and

5.7.2.3 other places as may be available.

Bylaw 8: Communication to local Community

8.1 When anything needs to be communicated to the inhabitants of the Municipality, Council will make use of one or more of the following means of communication:

8.1.1 Notices in the local newspaper or newspapers of its area and in the appropriate language for its area;

8.1.2 notices in a newspaper or newspaper circulating in its area and decided by the Council as a newspaper of record;

8.1.3 radio broadcasts covering the area of the Municipality;

8.1.4 distribution of flyers, pamphlets and/or posters;

8.1.5 loud hailing in the area concerned;

8.1.6 announcements at church services and schools; or via communications through its ward committees.

In addition to the above bylaws, the principles for community participation as set out in the National Policy Framework for Public Participation (South Africa, 2007) were considered. Table 5-3 summarises the principles of the act.

Table 5-3 : Principles of Community Participation

Principle	Examples of applying these principles
Inclusivity	Identifying and recognising existing social networks, structures, organisations, social clubs and institutions and use them as a vehicle for communication.
Diversity	Ensure that different interest groups including women, the disabled and youth groups are part of governance structures.
Building community capacity	Solicit funding from external sources to train ward committees and IDP forums on their role in development and service delivery. Embarking on citizen education on all aspects of local governance.
Transparency	Engendering trust in the community by opening council meetings and processes to the public and encouraging attendance.
Flexibility	Being flexible in terms of time, language and approaches to public meetings and processes.
Accessibility	Conducting public meetings and processes in the local languages.
Accountability	Ensuring report backs to the community forums or ward committees at least on a quarterly basis.
Trust, Commitment and Respect	Ensuring that the purpose of the process is explained adequately, as well as how it will develop.

(South Africa, 2007)

The three factors that create a framework of trust and credibility and which act as enablers for all of the above-mentioned principles and regulations are (Walaski (2011:22):

- Perceptions of knowledge and expertise
- Perceptions of openness and honesty
- Perceptions of concern and care

With these guiding principles the dolomite risk awareness actions were approached and implemented. Peters *et al.* (1997) found that especially for government, an increase in the public perception of commitment increases trust and credibility. This commitment alongside the perceptions of expertise, openness and concern are key factors in gaining the trust of the affected residents.

5.7.2 There's a new drill in town (Drilling Phase 1)

When initiating a process such as dolomite risk awareness, the starting point is the scientists, technicians and officials who would have the initial encounter with the dolomite research process, but also those who had the first contact with the community. These stakeholders were the technical team working within the community doing research, as well as the officials facilitating the management and technical implementation of this process. These are the stakeholders that I had to prepare to engage with the community.

The geotechnical team would have the dolomite expertise, but other technical specialists involved in this process may not have been as knowledgeable about the risks of working on dolomite. Two aspects deserved attention in these initial research actions: the first was the general dolomite awareness, and the second was equipping technical stakeholders with knowledge of the social impact and social awareness component of the project. They would have to answer challenging questions on site and negotiate emotions and reactions to interventions. It would have been a very simplistic viewpoint to believe that just presenting the scientific facts concerning the risk would be sufficient to change the perceptions of a community (Cone *et al.*, 2013:348).

Because of this critical and sensitive first community encounter, a DRMS workshop, engineering workshop, ad hoc legal workshop and social awareness workshop were held, not only for the sake of project management, but also to create awareness among all officials and technical personnel on the risks of dolomite and sinkholes. These are the people who will have to enable residents to mitigate the anthropogenic risk. By starting with compliant infrastructure and building practices the resident can only apply the basic anthropogenic risk management requirements such as preventing ingress of water in order to reduce their overall risk. The aim was also to guide technical personnel on how to explain the DSI actions to affected communities so that the possible

reactions and the impact on the community could be managed correctly and proactively.

The information contained in the message that was decided on by multiple inputs had factual meaning, but symbolic and cultural meanings were also attached to the message conveyed (Kasperson *et al.*, 1988:177; Reynolds & W. Seeger, 2005:45). This social context frames the message, and the effect and value of the message could have been altered by politics and cultural factors. In planning the message and the way in which it would be communicated, socio-cultural moderators were considered in order to ensure the greatest potential for creating awareness.

The measures taken into consideration by me to moderate for this phenomenon in the compilation of risk awareness material were:

- multi-cultural input in message construction and framing;
- input from different levels of socio-economic realities;
- input from vulnerable groupings; and
- backdrop for message from their own familiar surroundings, culture and language.

These principles were implemented with all chosen methods of risk communication, especially concerning the design and scripting of the dolomite risk awareness leaflets.

A drilling rig entering an affluent neighbourhood would not warrant a second glance, but in vulnerable communities, people stop their activities and observe from the moment it enters town. The news of a drilling rig entering town spreads quickly throughout the community.

The first action was to train drilling liaison officers. They were sourced by me from a local community training project and trained on the technical aspects of dolomite and the research actions taking place (AGES, 2013d). In order to train the liaison team, knowledge products had to be developed based on the integrative risk awareness framework. The training was done at the hand of a few burning questions they would most probably be asked concerning dolomite, sinkholes and the DSI. The drilling liaisons officers were also made aware that their only interest should be creating awareness, and not to have a vested interest in how their audience reacts to their message (Morgan *et al.*, 2002:5). The only goal of the dolomite risk awareness actions was to help affected residents toward their best interest (Morgan *et al.*, 2002:7).

5.7.3 The social map

At this stage, affected residents were already enquiring through the Dolomite Management Desk (DMD) that was established at the beginning of Phase B of the DRMS to manage building plan enquiries and general enquiries. Stakeholders wanted to access the Indicated Risk Map that resulted from the Phase A research. The Indicated Risk Map could not be disseminated, as the

risk was not quantified and it could create confusion and unnecessary panic. The decision was made by me to compile a social awareness map (AGES, 2013d). It would follow the broad outlines of the indicated risk area, but the DRMAs would not be visible and the outlines would be less harsh than the Indicated Risk Map (AGES, 2013d). It would consider the social boundaries that exist, such as wards, streets and neighbourhoods within the indicated risk areas.

The social awareness map (Fig. 5-9) became a useful tool for the town planners and building inspectors. A moratorium was placed on all new developments, housing or extensions to residences until the research had been completed and the DRMAs finalised. This map was used to help stakeholders understand why a moratorium had been placed on extensions or new developments in their area.

This map was enlarged to A1 size and used by the DMD and liaison officers on a daily basis to educate, inform, consult and involve affected residents. It has been used for press releases, press conferences and information sessions with ward councillors.

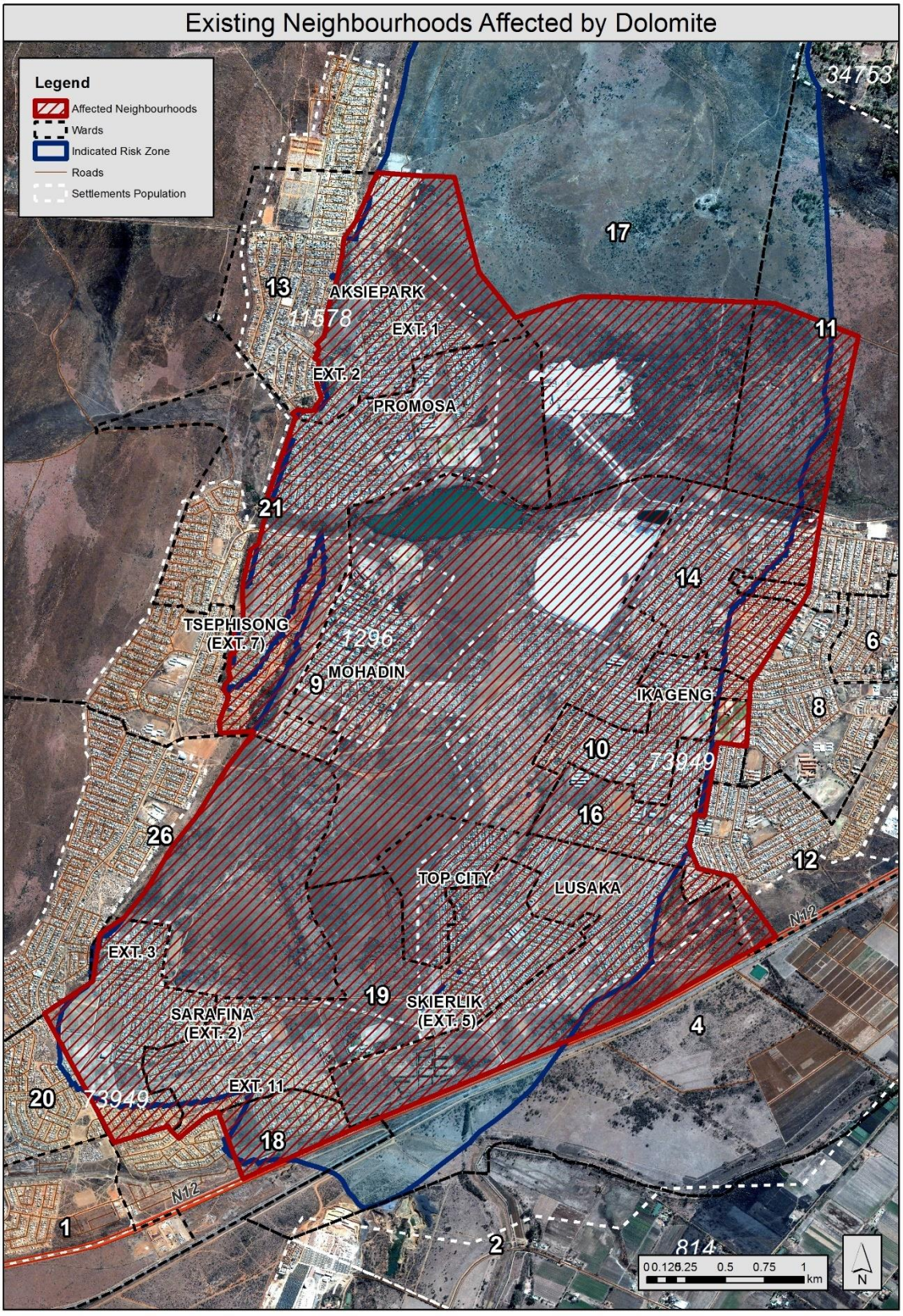


Figure 5-9: Social Awareness Map (AGES, 2012).

The DLOs were deployed on site alongside the drilling rig. Included in their job description was the task to keep the perimeters safe as part of the health and safety procedures, as especially children wanted to approach the drilling rig. While this protocol kept interested residents at a distance, it provided DLOs the opportunity to explain to them what was happening on a technical level. The team deployed were trained by me in various contact sessions.

Where boreholes were sited, the ward councillor of that particular ward was contacted and invited to be on site. Concurrent with this invitation, the ward councillor and committee members were invited for a focused awareness session. They were also shown maps of how the indicated risk affected their ward (AGES, 2013d).

Before the drilling operations started in the mornings, the DLOs visited each home along the street where the drilling would take place. They explained the drilling process, as well as the fact that there would be dust and noise for a while. The ensuing rehabilitation of the borehole and drilling waste was also explained. When a school was adjacent to the site, the principal was visited and invited on site. Both the onlookers and residents living along the street signed a register to acknowledge that they had been made aware of the risks associated with dolomite and sinkholes (AGES, 2013d). The DLOs kept a register and incident report of every concern or comment from the community, including contact details. Concerns were followed up by either the technical team or the liaison team. The incident report not only served as a reflection of concerns, but also of positive attitudes and interest. I used the registers to plan the actions of the next day.

Residents and officials reported holes or cracks in the ground to the team and the technical team promptly followed up, accompanied by a liaison officer. The findings were reported through the DMD to the SC. In certain cases, the technical team would revisit the erven to monitor the status of holes or cracks.

At this early stage, it was already clear from the information gathered by the DLOs that many damaging narratives were circulating in the community. Many residents did not even want to provide their signature to confirm that the awareness campaign had been conducted at their homes as they were afraid, they might be signing their homes away. The known narratives were the following:

- Dynamite was planted underneath Ikageng, Mohadin and Promosa during the Apartheid era so that they could be blown up should it be called for;
- the TCC has established that gold deposits were found underneath these areas and they are using dolomite as an excuse to resettle them to gain access to the gold. The same narrative was also repeated with oil and diamonds being the motive;

- the TCC wants to build a shopping centre and other developments on the so-called dolomitic areas as soon as they have removed the residents;
- there is no such thing as dolomite. It is a snake under the ground that creates tunnels; and
- during the Apartheid era people were moved with dolomite falsely being cited as the motivation, and now the TCC are doing the same.

Some of these narratives are discussed with the findings of the focus group discussion conducted with project closing and that will be coded for emergent categories. The liaison team started redressing the false narratives with accurate information. References to the narratives were incorporated in the script of the drilling liaison and door-to-door risk awareness.

5.7.4 The media

The SC decided that a press release should be drafted, and a media conference should be held to explain the status of the project, since affected residents and ward councillors were voicing concerns about the financial implications of additional DSI studies. They expected a response as to why previous studies, such as the pre-Phase A studies, had not been sufficient. The immediate risk communication needs of a community are always to reduce uncertainty through a basic awareness of the facts of the case (Reynolds & W. Seeger, 2005:50). The decision was made to draft a press release in response to the concerns raised. The whole of the team contributed to the press release, but I compiled all the inputs for the final copy.

The press release was adequate to address the concerns of the average affected resident but had little effect on politicians. It was clear no answer would be satisfactory or fit into the rhetoric they were supporting. At this stage, political factions were developing, and the issue of the funds allocated to the DSI led to accusations of misappropriation of funds. During the preceding elections, certain politicians used the argument that no phenomenon such as dolomite existed, as one of the pillars of their election manifesto. The dolomite investigation posed a serious threat to their power base. The community welcomed this new narrative as it implied that they did not have to fear anything and would not be resettled. As the focus group findings later in this thesis indicated, the most vulnerable of the affected residents do not necessarily have access to media, which means this message to reduce fear of resettlement may not have had the effect that was expected.

On the 28th of February 2013, the Human Settlements Portfolio Committee in parliament released a statement that pronounced that the presence of dolomite was no longer an excuse for the state to refuse to build houses for the poor (City Press, 2013). This confirmed the framing of dolomite as a political issue. As housing is one of the most basic needs of human beings, it came as no surprise that the shortage in housing provision needed a scapegoat. This accentuates the

importance of housing and land use issues and the effect of decisions such as this for the proliferation of low-cost housing on dolomite.

In South Africa, the post-apartheid constitution's promise of housing for all is an example of attempts to try and solve a problem with much legislation, but not enough state resources to realise the goals (Levenson, 2018:124). Given its limited resources, the already beleaguered welfare state is experiencing difficulty in keeping up with the increasing demand of urbanisation. The effect is that residents enter a constant competitive state for housing and resources, with no recourse but to live informally.

The matter was further complicated by non-compliance to the moratorium on building. Residents found it difficult to comprehend that some affected residents were building while others were not permitted to build. Within this setting, awareness became complicated and the campaign had to be intensified to waylay the ever-mounting list of narratives that were emerging and had to be addressed by me.

5.7.5 The Dolomite Management Desk

During the first rotary percussion drilling, the DMD was established and managed by the dolomite research consultancy. By calling the dedicated mobile phone, information regarding dolomite or the research process could be obtained. Details on the moratorium placed on building plans could be accessed using this avenue (AGES, 2013d).

A statement was compiled together with the SC to elucidate the moratorium placed on building and building extensions in indicated risk areas. This statement was provided to all residents submitting new applications. The building plans were still submitted to the TCC building office, but the DMD then provided input to the TCC regarding the status of dolomite on the stand. An additional notice was drafted to explain the current process and expected progress. This notice was distributed to all building and building extension applicants, together with a copy of the press release and a map of the indicated risk area (AGES, 2013d).

This process was supposed to involve government departments and structures regulating RDP and BNG projects, but communication in this regard became increasingly complex. This meant individual building applications went through a rigorous process with consultation sessions, but low-cost housing projects proceeded. It was these projects that presented the greatest concern for anthropogenic risk on dolomite.

5.7.6 Karst worldwide

In the process of conducting workshops, focus sessions with ward councillors and sessions with

affected residents, a concern raised to me by residents was that it seemed that previously disadvantaged residents were affected and not the affluent parts of Potchefstroom. They needed perspective to judge their own situation in terms of the rest of the world. The issue was acknowledged by including maps of the world karst terrains as well as information on which other regions of South Africa were underlain by dolomite. The issue that was the most challenging was that Potchefstroom is not affected by hazardous dolomite. The low-income housing areas seemed the most afflicted by this risk and they were expected to mitigate the anthropogenic factors.

Morgan *et al.* (2002:24) argue that risk communication should not "talk down" to stakeholders but should assume that the stakeholders are interested in the awareness material and capable of mastering it. This statement cannot be universally applied, especially not in developing countries such as South Africa, but could be a communication approach to certain stakeholder groupings such as technical and research partners. The examples of risk awareness material that could be accessed worldwide were clearly aimed at educated audiences and comprised lengthy booklets or pamphlets in fine print filled with technical details and warnings. This approach would clearly not meet awareness goals for a vulnerable community with low levels of literacy.

The primary objective was therefore to create an illustration that could be used to explain the subsurface incidence of dolomite and the effect ingress of acidic water and water abstraction had on karst. A very elementary illustration would suffice. The illustration in Figure 5-10 published by watermatters.org, proved to be ideal. It was used daily in awareness interventions.

5.7.7 Phase B research awareness leaflet

The second objective was for me to develop a leaflet that would illustrate dolomite-related risks informally and in images to which residents could relate. It had to explain dolomite and the presence of the drilling rig. A conversation script was developed, and photographs were taken at recognisable venues within the affected areas with local residents as the characters. It is pictured in Figures 5-11 and 5-12.

The leaflet was made available in English, Afrikaans and Setswana. It was reviewed by community members and technical personnel to ensure that the message was effective and clear. Morgan *et al.* (2002:4) compare random and unproven communication to distributing untested medication. The awareness team supported this argument and I continued the review process until the feedback proved that it complied with cultural and language requirements.

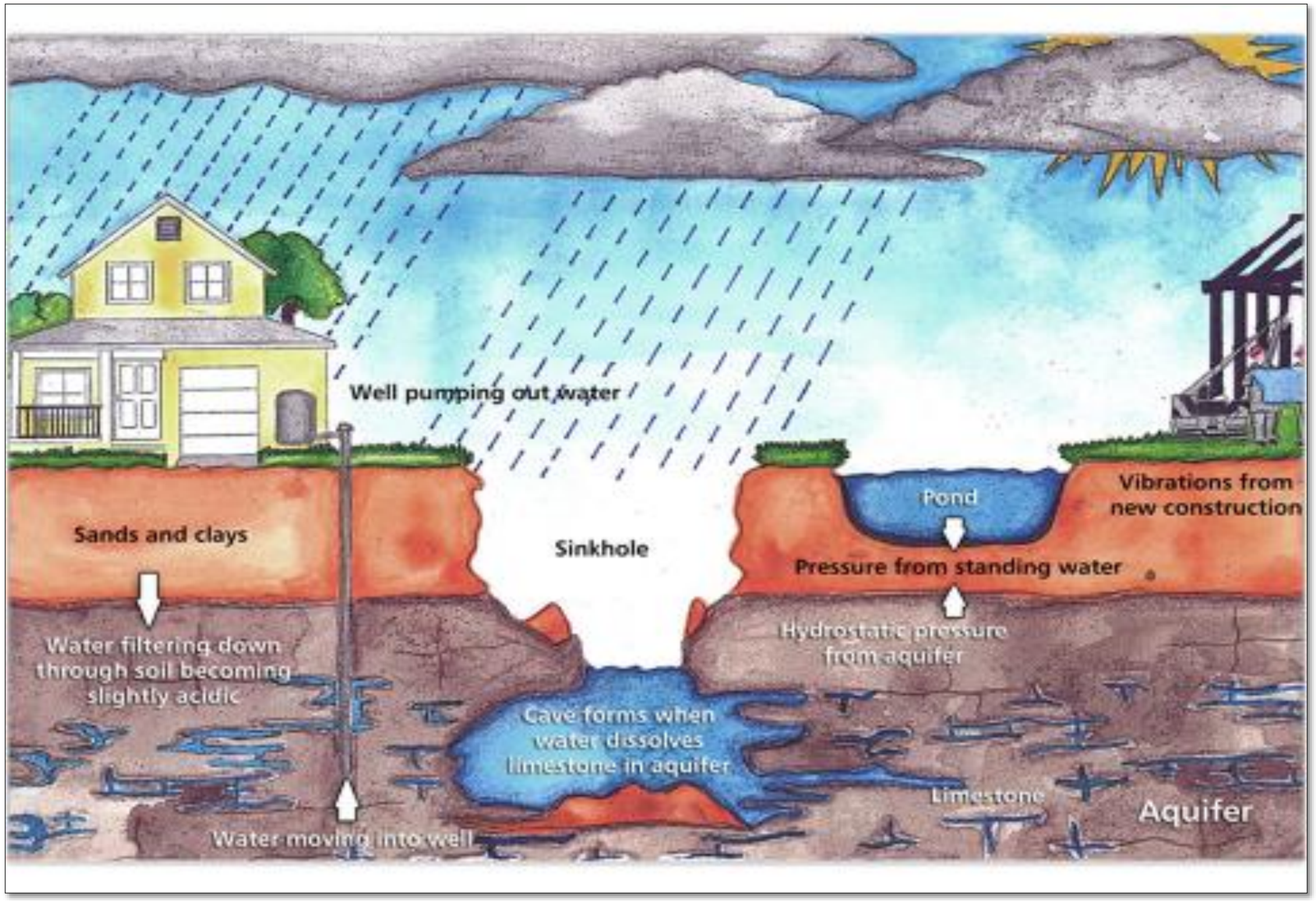


Figure 5-10: Sinkhole formation (Source: watermatters.org)



Figure 5-11: Dolomite risk awareness leaflet 1 (AGES, 2013a)

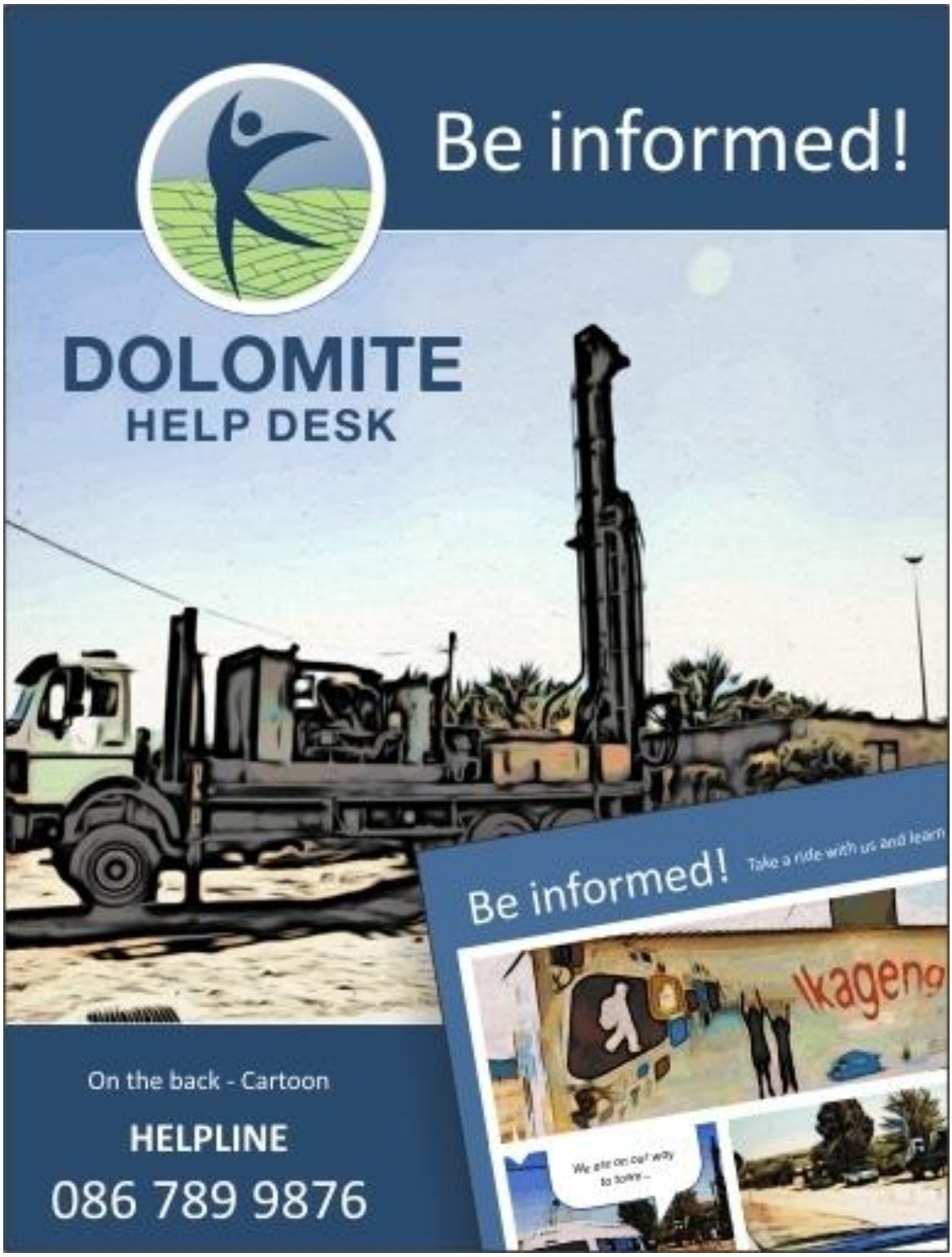


Figure 5-12: Poster on reverse of leaflet 1 (AGES, 2013a)

5.7.8 Drilling Phase 2

During the second phase of drilling, liaison officers were used on site again to prepare the community for the drilling and to conduct a general awareness campaign surrounding the site. They used the opportunity to disseminate information on infrastructure care and on how and where to report leakages and other infrastructure problems.

A focused awareness campaign of the mitigation of anthropogenic risk was conducted for three weeks. The campaign targeted taxis and taxi ranks as high volumes of affected community members pass through this point daily. Liaison officers visiting the taxi rank and travelling in the taxis tried to create awareness through informal conversations.

5.7.9 Radio

Radio as medium with wide availability and flexibility is an ideal way to create awareness of an issue (Reynolds & W. Seeger, 2005:49). A senior geologist and I from the risk awareness team received a slot in a breakfast show on the local radio station, Aganang FM, to explain some of the burning issues concerning dolomite. The listeners called in afterwards with questions of their own. Their questions were translated to the team and they could respond. Only after the show one of the social monitors informed the team that a listener asked a politically sensitive question. The DJ did not translate it but asked a different question. This was damaging because it seemed as if the team did not want to answer the question and it contributed toward mistrust.

5.7.10 The Tlhalefa campaign

A campaign called Tlhalefa[17] was initiated by me to target low-income housing areas that have already been identified as being at high risk. Promosa, Sonderwater (Ikageng) and Sarafina (Ikageng) were included in the first stage of this campaign. As part of this campaign, a door-to-door awareness campaign was run by a team of well-trained social technicians. They commenced each visit with three questions to establish a baseline for the levels of awareness in the community. Most residents knew about dolomite but could not explain what it was or did not know how sinkholes form. The technicians under my instruction then explained dolomite and sinkholes using the leaflet and illustration. They combined dolomite awareness with infrastructure awareness and explained the correct channels to follow for reporting infrastructure failure. They were provided with contact numbers for the TCC Department of Infrastructure and for the Disaster Management line. The community was also encouraged to report infrastructure failure in dolomitic areas to their ward councillors. Out of this awareness campaign queries about building plans were

[17] Tlhalefa is a Setswana word meaning “to know more.”

brought to the attention of the social team. These queries were reported to the DMD, where it was either addressed by contacting the residents telephonically or by visiting their homes.

Community members indicated to the awareness team that due to criminals entering their yards and politicians campaigning, they had uncertainty as to whether visits from the team were legitimate visits. The community indicated that the liaison team would be welcomed if they could be identified as such. Coinciding with the development of a dolomite logo for the website and helpdesk, clothing worn by the social team working in Ikageng, Mohadin and Promosa were branded with this logo. I also issued them with branded caps.

A new social map was compiled by me for Ikageng, Mohadin and Promosa to indicate priority focus areas for intensive awareness interventions for the following six-month period (Fig. 5-13). These priority focus maps were not for public access but were used as a planning tool for my team.

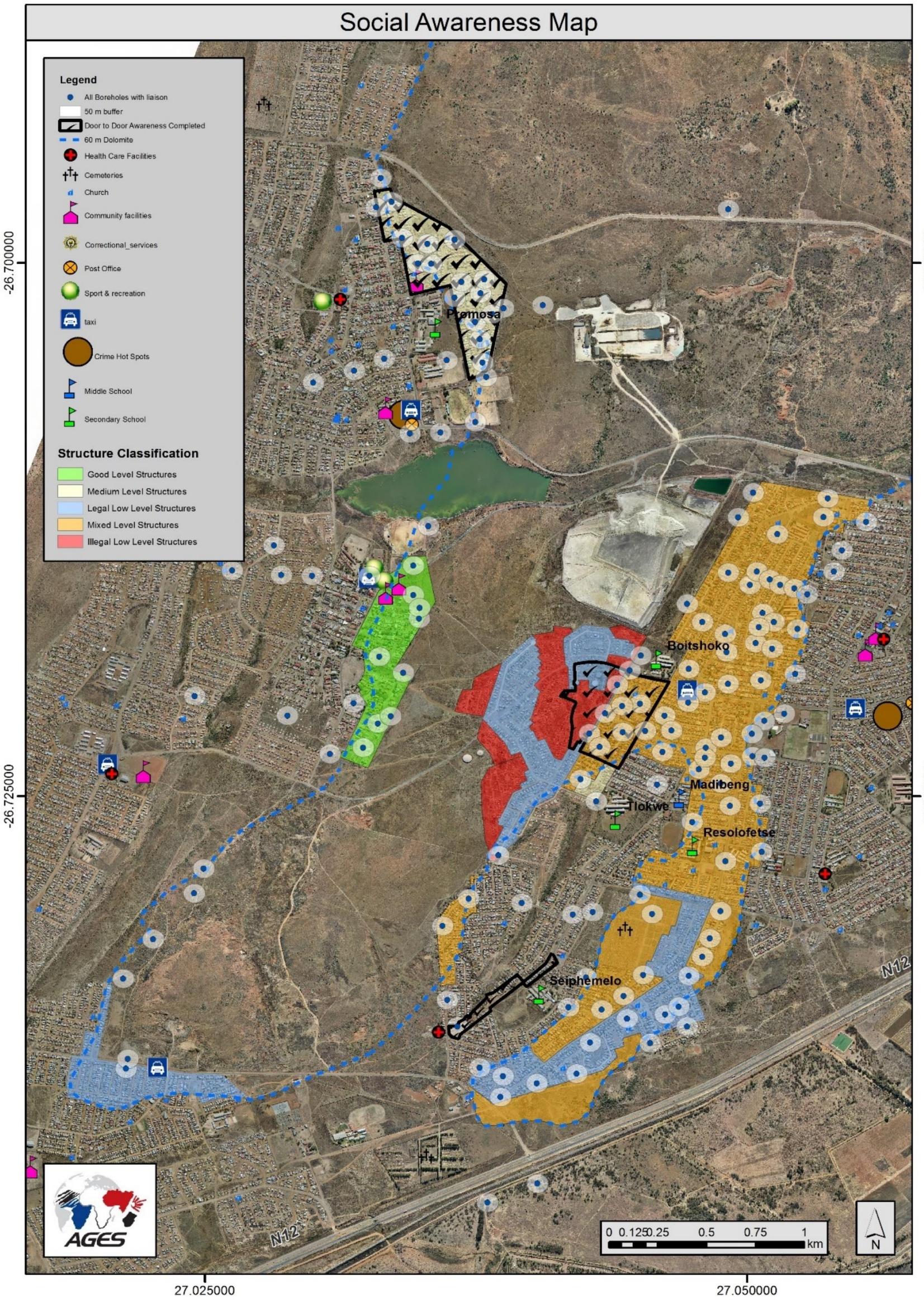


Figure 5-13: TCC Social Awareness Map (AGES, 2016a)

5.7.11 The Ikageng Reservoir resettlement

The technical report on the Ikageng West Reservoirs indicated that the reservoirs and associated infrastructure were non-compliant according to any minimum current standards and practice. The Ikageng West Reservoirs are underlain by highly weathered chert and dolomite residuum.

Based on the results of previous research done in the area of the Ikageng West reservoirs, the new drilling data and the status and geo-environmental conditions of the site, the area was classified as DRMA 4 with an inherent hazard class 8/8. These conditions indicated a high risk for the loss of life and infrastructure. The area surrounding the reservoirs was inhabited by 164 illegal and informal structures that were at risk. In this instance, a risk awareness campaign to mitigate the risk would not even be considered. Four rounds of awareness creation efforts were conducted to ensure that all the affected residents understood that they were at risk and would have to be resettled.

A Resettlement Action Plan (RAP) was compiled by me and the four phases of resettlement have been successfully implemented. This incident required comprehensive awareness and consultation and placed the risk awareness team in perilous situations. The theme running through most conflict situations could be connected to the housing dilemma. In Ikageng alone 50,3% of residents are awaiting housing. As part of this resettlement, people who have settled illegally would receive a serviced erf ahead of residents who had been on waiting lists for many years. One of the greatest challenges was to create awareness among communities adjacent to the reservoirs and the community at large about the risk and necessity to resettle these residents without delay. The surrounding communities are also at risk, living in informal structures with shared water points.

5.7.12 The subsurface model

Feedback from the door-to-door awareness campaign pointed towards residents experiencing frustration with understanding the subsurface conditions as it was not visible to the eye. This narrative was highlighted in the focus group discussion analysis done throughout the project lifecycle. Residents had difficulty understanding that on the surface they observed no problem, yet they were being told that their lives and homes were in danger. In response to this difficulty, a model as depicted in Figure 5-14 was built using the data from the Sarafina subsidence investigation. The model became the most effective tool for awareness creation. When closed, it resembles a quiet normal street, and when opened, it reveals the subsurface conditions. The houses built to scale can be lifted and inserted into the dolomite cavities, illustrating the magnitude of the cavities.



Figure 5-14: Sarafina subsurface model

5.7.13 Workshops

When conducting workshops, the first priority for me was to create awareness of the hazard of dolomite and the risks associated with this hazard. The affected communities were always at the centre of these concerns. As the anthropogenic factors that affect this hazard had to be addressed to reduce the risk, the technical officials and consultants that mitigate anthropogenic hazard should also be equipped to understand the risks of dolomite and to work safely on dolomite using compliant materials and methods.

In order to reach this objective, the following workshops were conducted, where stakeholders were provided with awareness material and guidelines for developments on dolomite:

- Engineering workshop
- Social awareness workshop
- Legal workshop
- Ikageng tailings dam workshop
- Disaster management workshop
- DRMS alignment workshop: Public safety
- DRMS alignment workshop: Housing and Planning
- DRMS alignment workshop: Financial and Corporate Services
- Strategy alignment workshop: Regional
- Strategy alignment workshop: Service providers
- Mitigation workshop

5.7.14 General awareness

The medical clinics adjacent to dolomite affected areas were visited by prior arrangement. At some clinics the awareness team joined efforts with TCC Disaster Management to make community members aware of the risk they face. Fieldworkers used the subsurface model to illustrate the formation of a sinkhole and handed out dolomite awareness leaflets. This created an opportunity for questions and concerns to be raised. During this campaign, small focus groups of affected residents were formed, and the perceptions and concerns of the residents were documented.

Most concerns centred on the fear of having to be removed from their homes and the possibility of not being able to receive RDP[18] housing because of dolomite. These concerns were considered

[18] Reconstruction and Development Programme providing low-income housing to previously disadvantaged beneficiaries.

and mitigated by being sensitive to their fears, as these stakeholders represented the most vulnerable of affected residents.

The response of the risk awareness team was to recommend that the door-to-door campaign be intensified as it provides for more time to explain issues to individual households and an opportunity for them to ask questions and raise concerns that can be addressed on the spot.

5.7.15 Alignment with infrastructure survey

As the technical team became aware of more reports of cracking homes and suspected holes, it was decided that there should be another round of focused awareness efforts to facilitate more practical information on how to react when encountering cracks and subsidences (AGES, 2013d). This also served the specific purpose of doing an infrastructure survey in order to inform technical team members as to the possibility of increased risk to the community.

During the initial door-to-door awareness campaign and the infrastructure survey, the DMD was informed of a concern or possible incident. Imagery of the crack, structural damage or hole was sent to the DMD electronically.

The DMD consequently dispatched a geologist to conduct a site inspection. A report was then provided to the DMD to either submit to council or recommended for further investigation. The process was facilitated by an awareness team member with the homeowner in mind. The liaison officer explained the process and the monitoring actions to the homeowner. The infrastructure survey therefore opened up the opportunity for follow-up with infrastructure specialists to monitor cracks, which in turn informed the dolomite scenario as a whole.

The awareness team ensured that the concerns of the homeowners were addressed throughout. Additional awareness sessions with geologists in combination with the use of the dolomite model were arranged.

The dolomite risk awareness efforts at the homes surrounding the Sarafina subsidence event was prioritised and relied not only on the owners reporting infrastructure failure by means of the survey, but also on physical inspection by the fieldwork team. The application of an integrated awareness approach in Sarafina was an effective way to monitor changes in sinkhole activity. In addition, the team could also monitor concerns, levels of community awareness, emotions and narratives concerning the progress with and outcomes of the research process.

The media and door-to-door awareness campaigns caught wind of a perception that the technical process had been prolonged more than needed and that its results were not disclosed and disseminated adequately. This implied that their tolerance levels were already reduced and

therefore a careful strategy on disclosing information and introducing mitigation was essential.

5.7.16 The Kanana subsidence event

During September 2013 while the TCC Department of Infrastructure was digging a trench in Kanana, Ikageng, a sinkhole opened up in the midst of seven homes and created pandemonium in the surrounding community. The research team commenced immediately with the drilling of five rotary percussion boreholes, a detailed gravity survey and a 3-D resistivity tomography survey. This research revealed that the bedrock was overlain by highly weathered chert rubble material in a silty clay matrix with traces of wad and dolomite residuum (AGES, 2013b; AGES, 2016b).

The bedrock represented cavernous conditions typical of extreme karst conditions. The overburdened material was characterised by highly weathered material, with extensive cavity formation. The entire profile surrounding the dolomite-related feature represented active subsurface erosion and a very late stage of incipient sinkhole formation represented by progressive collapse of the roof of the void (AGES, 2013b; AGES, 2016b).

Based on the geophysical analysis, the subsurface profile of the areas where the drilling had taken place was compared to the areas where no drilling had taken place yet. Based on this, the affected erven were identified and classified into 1st, 2nd and 3rd order erven for immediate resettlement (AGES, 2013d; AGES, 2016b). A RAP (AGES, 2016b) was compiled for this incident and four rounds of door-to-door awareness creation was performed to communicate the risk associated with this hazard and the resulting resettlement process to residents. Reynolds and W. Seeger (2005:44) found that risks such as dolomite and sinkholes that are perceived as being unnatural and curious create great uncertainty. This was confirmed during the Kanana incident. The most obvious route for vulnerable residents were to be guided by either scientists, government or politicians. As fear played a pivotal role in this vulnerable community, most heeded politicians who advised them that any sinkhole can merely be filled with soil and the community would not have to be resettled. This was said to ensure that their political base remained intact for upcoming elections, as resettlement could place voters a different ward. Although it was difficult to understand this perspective, Eiser (2004:6) view that this subjective representation of their reality should be seen as a legitimate alternative reality that may take time to mitigate was taken as guideline to approach the fear and uncertainty of the community.

After this, many meetings and awareness sessions were conducted by me within this community. However, due to logistical constraints such as the availability of erven and political resistance to resettlement, the resettlement has not yet been implemented. Figure 5-15 shows the Kanana

subsidence event and the precarious situation of surrounding residences.



Figure 5-15: Kanana subsidence

5.7.17 Political climate

The stakeholder who would gain the most from or has the most power to influence opinion and process will have the greatest influence on the community's attitude towards this project. It was therefore extremely important to acknowledge and involve these stakeholders. These stakeholders included the geotechnical team, social scientists, ward councillors, ward committees, churches, schools and the media. In the period approaching the 2014 elections, the politicians representing all parties played a pivotal role in the perception of dolomite risk and the general attitude towards mitigation of the risk.

The irritation with the perceived lack of transparency of results transposed on the general feelings of uncertainty and political turmoil, creating a potential flammable situation that needed to be mitigated for the DRMS to be implemented (AGES, 2013d). The perception of a lack of

transparency arose because the TCC acted within their primary obligation to ensure that only the most critical information is made public (Fischhoff, 1995:140). In an effort to create a secure climate for implementation, the narratives, social awareness levels and potential barriers had to be identified timeously and addressed while still on a manageable level. If levels of mistrust and frustration escalate, the mandate of the TCC to implement the DRMS and the mitigation of the dolomite risk would be seriously impaired.

The social monitoring included the liaison and follow-up of queries addressed to the DMD. These queries and concerns had the potential to create conflict and uncertainty. The perception of impact appeared to be more dependent on the perception of how adequately authorities managed the risk than the possible impact of the risk itself (Kasperson *et al.*, 1988:178). The mistrust and politicising the DRMS generated confirms the focus on the perception of successful risk management in contrast with the actual risk posed by dolomite instability. There was also disagreement on how risk is defined. Both the TCC and affected residents believed that the risk exists, but the residents felt it was only necessary to move if a catastrophe was imminent, while the TCC interpreted research and decided that the risk was significant enough to resettle residents in order to pre-empt disaster. In this process the vulnerability of these residents was underestimated by all, including myself. Our understanding of how vulnerable they were, did not match the reality of the compromised position in which they found themselves.

5.7.18 The risk of risk communication in the media

During the risk communication workshop, it was proposed that quarterly media conferences be held to update all stakeholders on the progress and implementation of the DRMS. According to Walaski (2011:2), our current culture relies constantly on verbal and written messages to inform us of the risks we face. These messages do much more than inform us. They wield power to mobilise large groups of people and to alter their behaviour and perceptions (Walaski, 2011:2). The media should therefore always be considered as one of the most powerful mechanisms in risk communication and should be managed wisely. Naturally, as mentioned before, the caveat is that the people who have to hear the message should have access to media messages.

A media event hosted in November 2014 received wide coverage in the media. This event afforded the TCC an opportunity for an interview on national television, which created awareness of the necessity of a DRMS. The media received transparent information on the status quo of the DRMS implementation yet chose to focus headlines on the wave of negativity from individual community members (Fig 5-16). The moratorium on new developments was still an issue, as housing developments were also halted in the process. The conclusion reached was that the media should receive additional awareness information as to the implications of fear mongering

and sensationalism on the mitigation of the dolomite risk.

During the aftermath of the Kanana subsidence event, the media reported on the frustrations of the affected residents about having to leave their neighbourhood and homes behind (Figure 5-17). In the process of different role players releasing information, a map was provided to the media. It was at that stage classified as confidential and was earmarked to be provided to the affected residents at a later stage during consultation (Herald, 31 October 2014). Although this was an honest oversight, it did flag the possibility that confidential information may be inadvertently divulged. Fear of leakages must not drive the TCC towards over-protectiveness and secrecy (Gould, 2012:4), but should highlight the sensitivity of access to information.

The publication of this map led to close cooperation between the TCC and dolomite risk awareness role players to agree to the levels of disclosure of documentation and information. The TCC spokesperson and communications department now confirm all statements and awareness material with other team members before its release to the media. Results of the focus group done at the conclusion of the project discussion point to affected residents specifically asking for more scientific information.

Dolomite places residents between a rock and a hard place

Victor Boqo

More than 80 residents staying in Boikhutso Street in Ikageng are to be relocated to Mohadin.

This comes after Tlokwe City Council appointed Ages to drill and test the ground for dolomite in September last year.

According to the municipal spokesperson, Mr Willie Maphosa, council has accepted the Dolomite Risk Management Strategy that was presented to it following intensive studies on the prevalence of the dolomite in local residential areas.

The measured dolomite risk management investigation has indicated that people residing in the Kanana area, next to the old Ikageng cemetery, are at inherent risk and should therefore be relocated as a matter of urgency. According to the report, there is no level of mitigation that can salvage the situation.

However, Maphosa said it had been agreed that resettlement would be embarked upon only as a last option, and that resettlement would not be undertaken on a large scale.

The relocation programme has been divided into three phases in order for the process to go ahead in a seamless manner.

The first phase consists of relocating ten households with immediate effect. Alternative stands have been identified in the Mohadin area.

The second phase comprises twenty one households whilst the third and final phase will involve 51 households.

"This is the first time that the municipality has embarked on such a task and many lessons will obviously be learned in the process. The co-operation of the households concerned, and the community in general, will be critical to ensure that lives are spared from potential danger. The area from which the residents are being removed will be cordoned off so as to avoid future invasions.

It is expected that the relocation process will be completed before the end of the year due to the urgency of the matter. Discussions with individual home owners for re-imbursement or compensation will take place immediately," says Maphosa.

According to Ages, a pre-risk assessment was conducted in the direct vicinity of the Kanana's dolomite-related instability feature. It was ascertained that at least the following houses may be adversely affected by instability caused by the sewer pipe. Based on the assessment, the coloured erven as shown in the photo have been prioritised.

The red stands are the most at risk and highest priority, followed by the orange and yellow as second and third order stands respectively.

But dolomite risk or not, the residents are up in arms and are firmly opposed to being relocated. Ms Baeng Molefe is adamant that she is there to stay.

"We have being staying here for the past ten years now. How can they expect us to give up our homes just like that? Who is going to pay for school fees and transport once we have been moved to Mohadin?" she asked angrily.



The Ages report shows the 82 houses - red, orange and yellow - that have been affected by dolomite and have to be relocated.

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Figure 5-16: Potchefstroom Herald, 31 October 2014

Council spends R4 million on dolomite studies but affected communities are 'gatvol'

Victor Boqo

Tlokwe City Council had set aside and spent R4 million to manage the risk posed by development on dolomite but, despite this massive spending, the 82 households affected in Kanana section next to the graveyard are 'gatvol.'

After the studies were done and a report handed over to council by Ages, it emerged that the affected households are at serious risk from dolomite instability and must be relocated as a matter of urgency. But the community is adamant that it is not going anywhere.

The studies consisted of two initial phases that focused primarily on the assessment of the risk, including geotechnical, geohydrological, land use, infrastructure and social investigations. The results of these risk assessments were incorporated in a report adopted by council in January.

On Monday, during site inspections, the MMC (member of the mayoral committee) of housing, Hodge Mokgethi, the housing manager, Laws Mohlomi, ward 4 councillor, Matlhomola Seobi and Stephan Potgieter of Ages, accompanied by a media contingent, were booed by some of the residents.

The community accuses the city council of withholding information on the dolomite findings and are questioning the reasons for relocation.

The municipality will soon be embarking on a door-to-door awareness campaign, and workshops.

During the media briefing, the MMC said Tlokwe Municipality has been proven to be one of a few municipalities in South Africa that already has a comprehensive dolomite risk management strategy (DRMS) in place, as required by law. The document has to be updated every five years.

The MMC insisted that the resettlement of households is regarded as a very last resort, and is only considered when all other mitigation options have been proven to be insufficient to effectively reduce the risk within tolerable limits. The municipal manager has already started the implementation process and the resolutions adopted in council.

The municipality is continually engaging with the affected homeowners to achieve the best alternative housing solutions possible.

"The community will be kept informed through an intensive social awareness, vigilance and risk communication programme over the following months and years," Molgethi said.

This includes both general and focused awareness, media statements, posters and cartoon pamphlets, liaison through community leaders and ward councillors, school programmes, workshops and door-to-door awareness campaigns.

"But the programme does not replace the responsibility of each affected community member to inform themselves about the risks at hand with regards to their specific development."

A workshop has been scheduled for 27 November, where ward councillors and their respective committees will be empowered to address enquiries from the community in more detail.

"Although there is no guarantee that sinkholes will never occur, as long as the risks are adequately and timeously managed, there is no need for panic."

The role and responsibilities of the typical homeowner or occupant include immediately reporting or fixing any leaking taps, water pipes, or sewer pipes on the occupied stand. No building or upgrading is permitted without authorisation or approved building plans. All new buildings or extensions to existing buildings should be reported to the Dolomite Help Desk at (071 268 9508) for evaluation by the dolomite specialist and approval by the Tlokwe City Council Building Department before construction may take place," Molgethi added.

"Council would like to assure the community that it is doing everything in its power to manage the dolomite risk to the benefit of all, and urges those affected to co-operate with the municipality and the specialist consultants."



These are the officials who addressed the media on the status of dolomite in the city: Matlhomola Seobi (ward 4 councillor); Hodge Mokgethi (MMC housing), Laws Mohlomi (housing manager), Dr Emily Blaai-Mokgethi (municipal manager) with Stephan Potgieter from Ages. Photo: Victor Boqo.

Was Ventersdorp Police Station robber(s) perhaps looking for this smashed laptop?

Victor Boqo

A burglary at Ventersdorp Police Station over the past weekend has raised eyebrows and questions.

son, Brig. Thulani Ngubane, confirmed that there had been a burglary at the Ventersdorp Police Station.

But Ngubane denies that the laptop came from the muncipality.

Figure 5-17: Potchefstroom Herald, 14 November 2014

5.7.19 Phase B: Dolomite risk awareness and the way forward

The mounting irritation with delayed dissemination of information led to the development of the second dolomite risk awareness leaflet (Fig. 5-18). This communique presented an opportunity for me to address the roles and responsibilities of the vulnerable homeowners residing on dolomite.

The drafting of another leaflet with similar content also provided the opportunity to repeat the intended message together with all the avenues employed to convey the risk message, amplifying the message by repetition from varied sources as suggested by Kasperson *et al.* (1988:181).



Figure 5-18: Dolomite risk awareness leaflet

5.7.20 Dolomite Management Desk processes

During Phase B it became apparent that the building application process was at the core of most complaints about dolomite research, feedback or deficits in awareness. The door-to-door campaign, visits by residents to the office of the consultant, and feedback from TCC officials collectively indicated uncertainty about and frustration with the perceived delay of the process.

The DMD increasingly narrowed its task of focusing on adhering to strict timeframes and developing a flowchart to use as awareness support (Figure 5-19). This flow chart was used with all building applications on dolomite to clarify the process and expected timeframes. During all risk communication actions, it became a useful tool to create awareness and transparency.

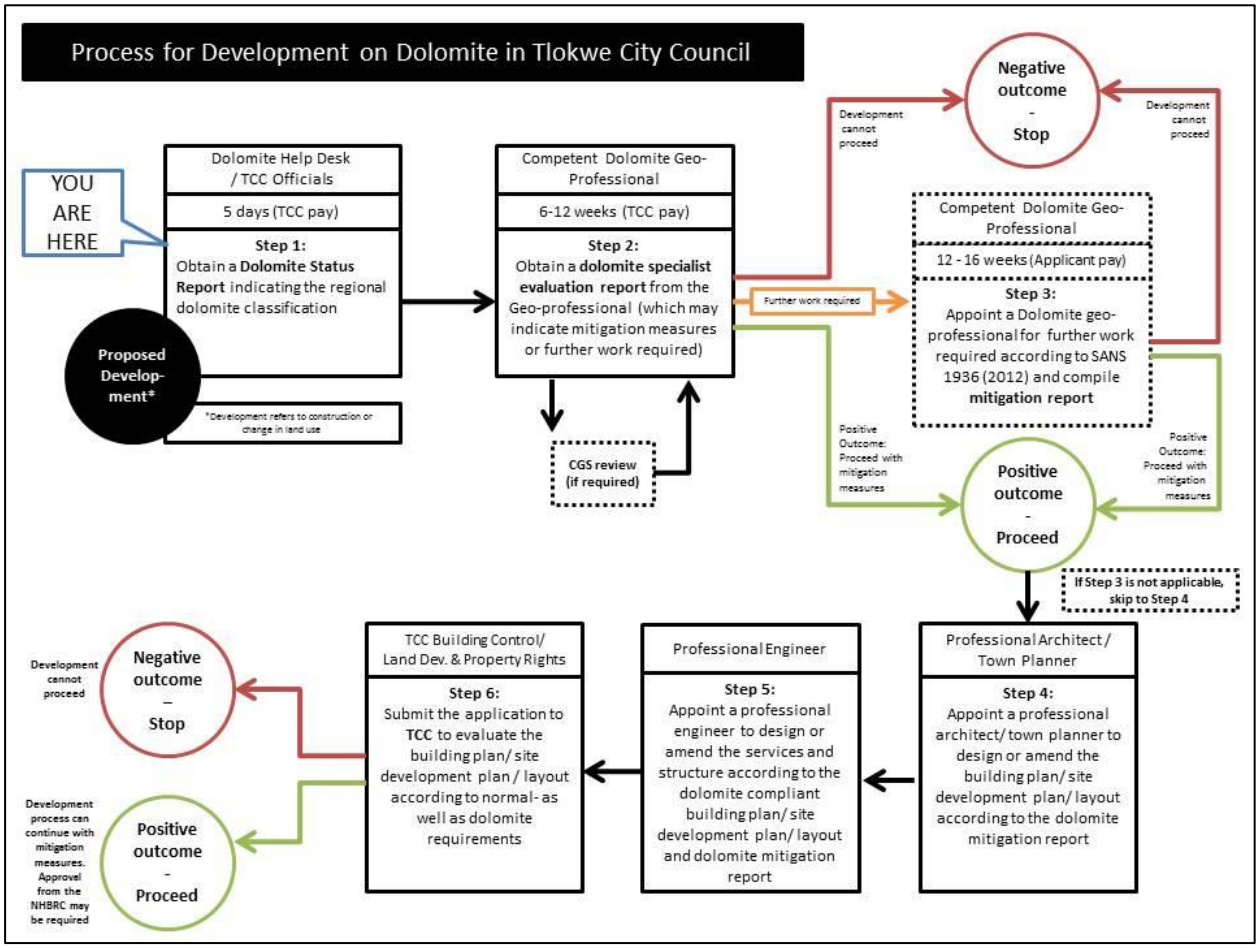


Figure 5-19: DMD Building application flowchart

5.8 DRMS Phase C1

The DRMS was officially adopted in 2014, which in effect introduced the third phase of the DRMPr (Potgieter *et al.*, 2016:1045). For this phase an implementation plan was developed based on the approved DRMS, council resolutions, DSC decisions and annual internal review processes (Potgieter *et al.*, 2016:1045). During this phase, it was proposed that the nomenclature be

adapted to define the objectives and actions of the DRCS more clearly.

The social processes involved to amplify the risk message according to the guidelines proposed by Kasperson *et al.* (1988:180) was recognizable:

- The risk message was processed through filtering and decoding of the signals;
- the message was shared and interpreted by means of interaction with the affected residents' cultural and peer groups; and
- these groups contributed to the validation and decision-making as response to the message.

It became apparent from the negation of the existence of dolomite or any problematic issues connected to it that the political leaders and community leaders framed the message interpretation and validation in terms of their own agendas.

5.8.1 DRMS implementation and mitigation processes

The following processes were included in Phase C1:

- Reporting continued
- Dissemination of reporting
- Implementation of recommendation
- Mitigation measures

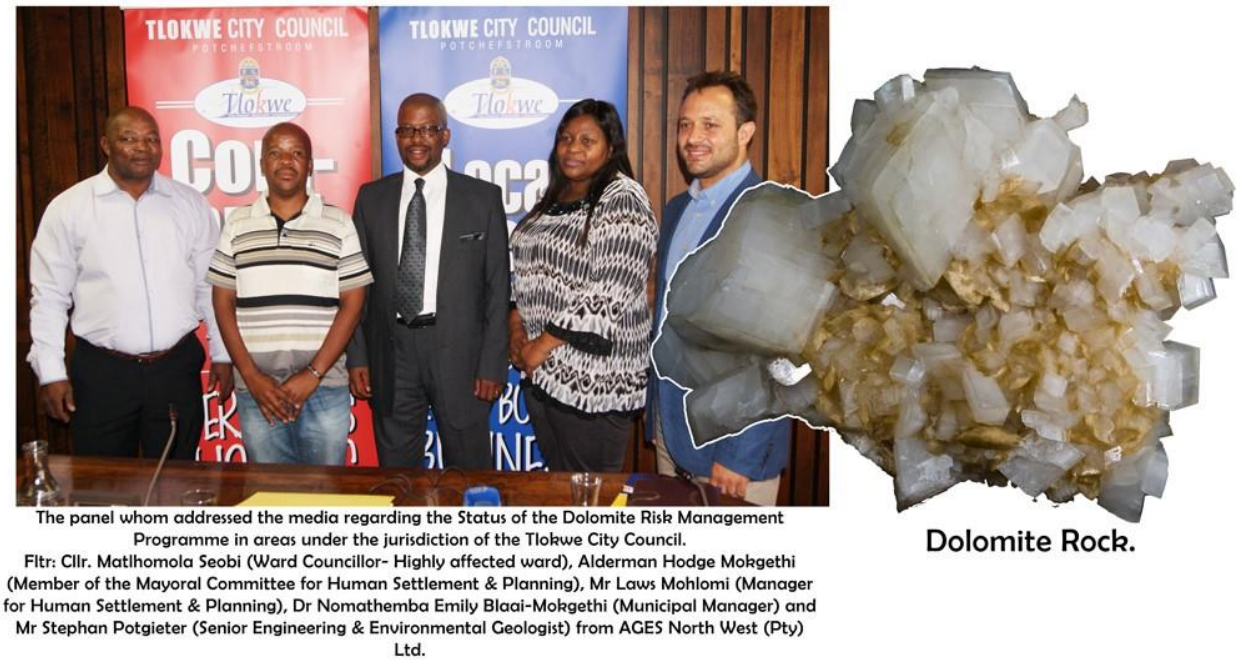
5.8.2 Risk communication workshop

As part of Phase C1 of the DRMS, a risk communication workshop was planned by me. The objective of the workshop was to revisit the risk communication actions up to date, to contribute innovative input and to receive feedback from the TCC and community members. A risk communication specialist was invited to present an overview of what risk communication entails.

The input received from this workshop was pivotal in assessing the actions implemented and possible future actions that should be included in the DRCS.

5.8.3 Media partners

After the first media conference the article showed in Figure 5-20 appeared in a regional newspaper (Platinum Kosh, 14 November 2014). It featured dolomite the mineral instead of dolomite rock. This had the potential to create confusion in a community already beleaguered by conflicting messages concerning dolomite. A closer association with the media and a more informed media could prevent these misrepresentations from occurring.



The panel whom addressed the media regarding the Status of the Dolomite Risk Management Programme in areas under the jurisdiction of the Tlokwe City Council.
Fltr: Cllr. Matlhomola Seobi (Ward Councillor- Highly affected ward), Alderman Hodge Mokgethi (Member of the Mayoral Committee for Human Settlement & Planning), Mr Laws Mohlomi (Manager for Human Settlement & Planning), Dr Nomathemba Emily Blaai-Mokgethi (Municipal Manager) and Mr Stephan Potgieter (Senior Engineering & Environmental Geologist) from AGES North West (Pty) Ltd.

Figure 5-20: Dolomite risk managed in Tlokwe

A key outcome of the risk communication workshop and the DRCS was that the media should be made partners in addressing the risk associated with dolomite. This process was initiated by employing the following actions:

- Individual journalists from local publications were invited by me to join the liaison team in a comprehensive dolomite risk awareness session;
- they received awareness material and an invitation was extended to visit me at any time or contact the team for the verification of information;
- media statements were drafted quarterly by myself as well as with each subsidence event as it occurred; and

- the TCC initiated contact with the media when a subsidence event occurred. The media was invited on site with the technical specialists and the risk awareness team to acquire relevant and accurate information.
- The media provided the TCC and dolomite risk awareness team with draft copies to proofread for technical accuracy.

5.8.4 Ward councillor workshop

At the beginning of 2015, a ward councillor workshop was held. Ward councillors were given an awareness presentation followed by an update on the progress of the programme. Ward councillors from dolomite affected wards received a file that included data and maps pertaining to their wards. They had an opportunity to voice their concerns and to ask questions to the team. Notwithstanding the comprehensive information sessions, the ward councillors and their role in the resistance to the mitigation of anthropogenic risk to vulnerable residents, appeared as one of the greatest obstacles to the community addressing and understanding the risk presented.

5.8.5 Door-to-door campaign

After a tumultuous time preceding the local elections and subsequent political instability, the door-to-door campaign was resumed. The door-to-door campaign could only be continued after the ward councillor workshop had taken place. The climate was still very tense. Within the affected areas, residents felt disenfranchised and perceived the municipality as not acting with integrity. The narratives employed for political gain preceding the 2014 elections were damaging and could not easily be mitigated.

As previously illustrated, an awareness plan can be discredited very easily by a few politicians or affected residents who act as if they have not received information (Moshodi, 2014:84; Muller, 2017:48). Within a legal framework, this could also have had major implications for the municipality, who to show their commitment and due diligence concerning awareness. In planning the new door-to-door campaign, the logistical planning of the campaign was so that it would miss a single structure or RDP and that it would gather as much proof of the awareness training done as possible.

In order to empower the TCC to continue the implementation of the DRMS, the door-to-door campaign was planned by a consultant but executed by the disaster management volunteers. They were briefed every morning and at the end of the day returned the data, which were subsequently captured by technicians and represented on GIS and spreadsheets. Congruent with other campaigns, the volunteers reported flagged incidents at the end of each day. High-risk scenarios were immediately reported from the field to the DMD and promptly followed up by the

liaison officers. Fig. 5-21 shows the map that indicates the proposed area demarcation for the awareness actions. In Fig. 5-22, the specific street demarcation for a TCC disaster management volunteer fieldwork team can be seen. When the team had visited a residence, it was highlighted on the map. Figure 5-23 provides a summary of all the door-to-door awareness visits done in focus areas up to the 2015 moratorium on risk awareness campaigning.

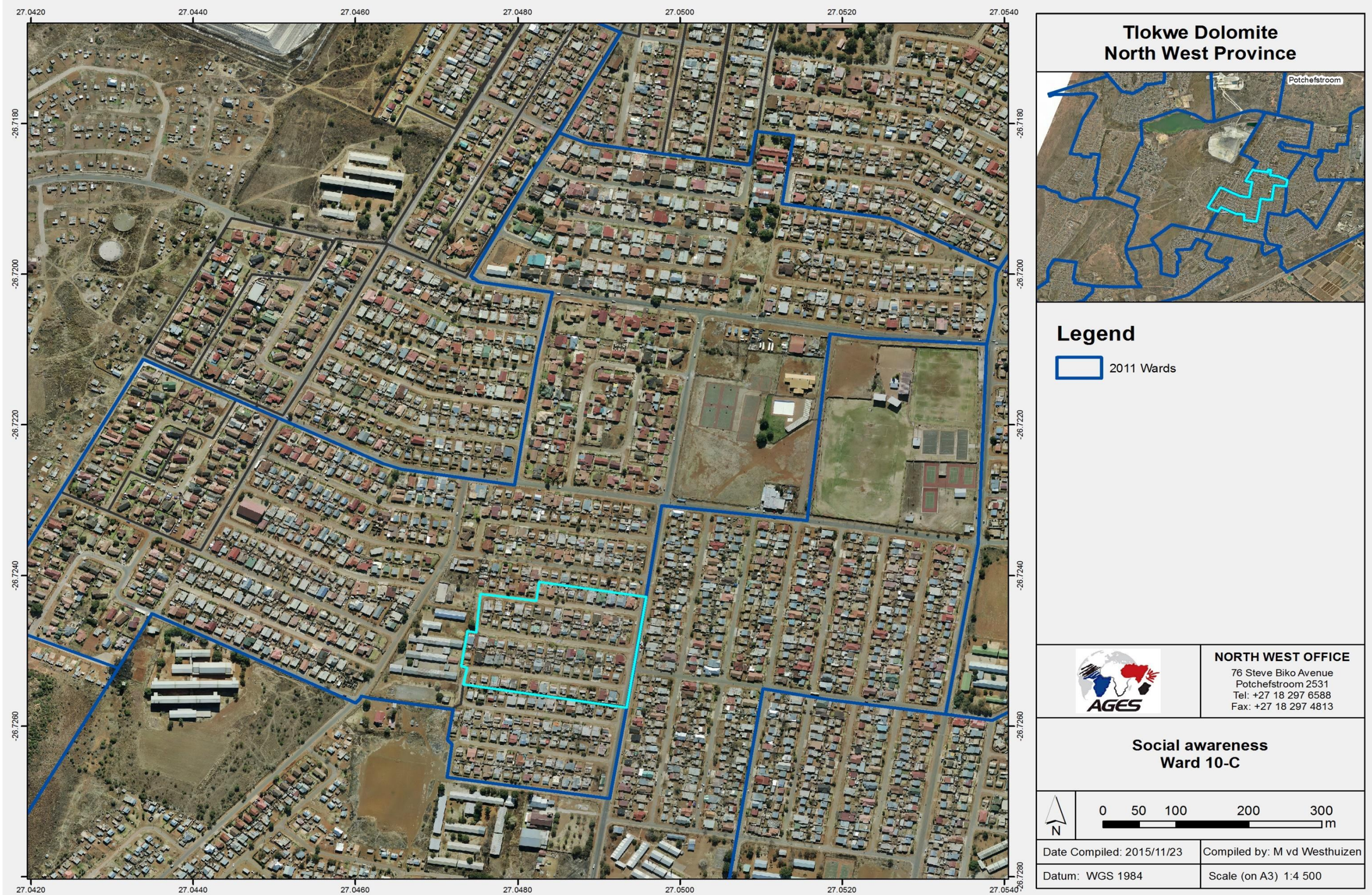


Figure 5-21: Door-to-door campaign ward planning (AGES, 2016a)

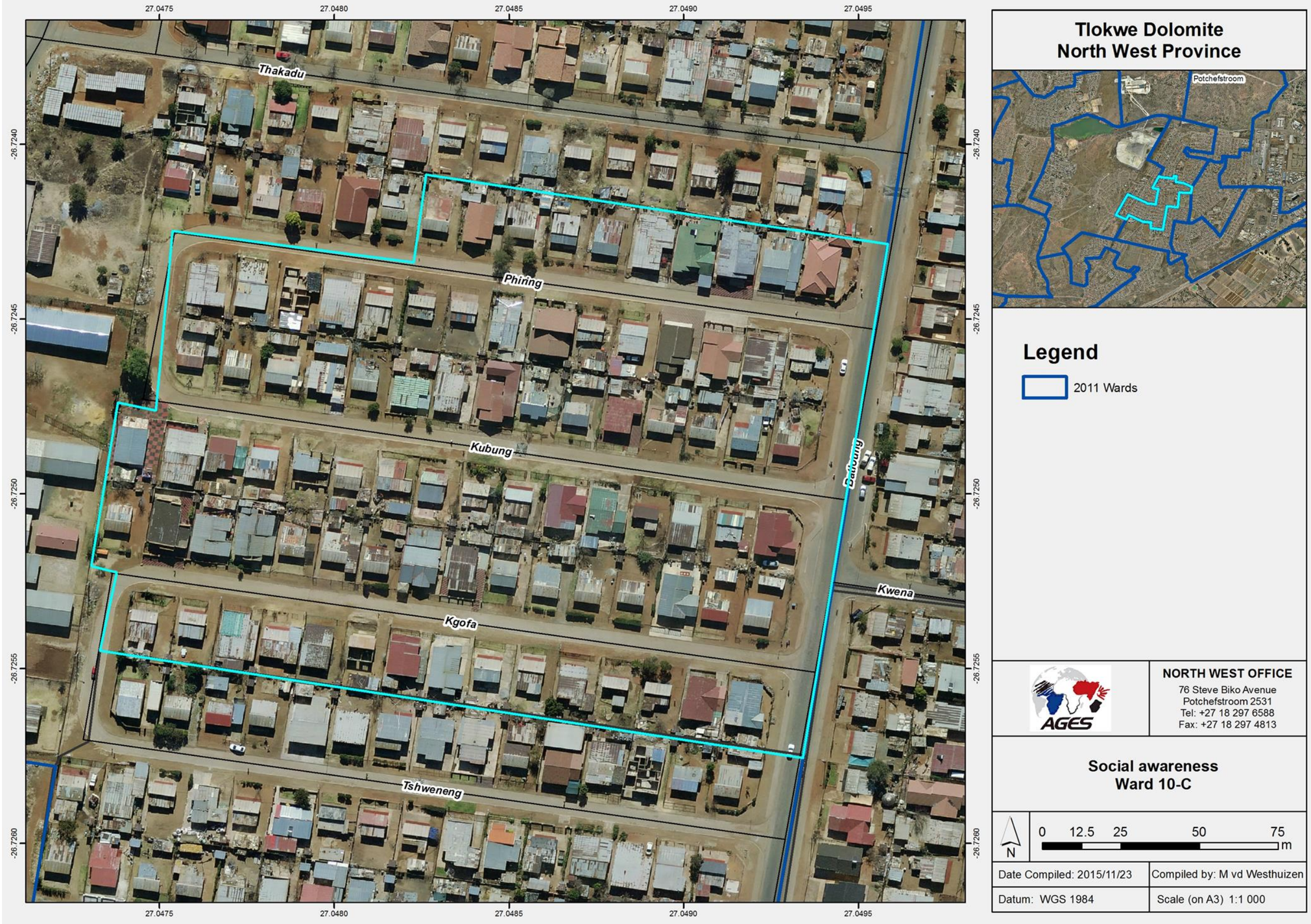


Figure 5-22: Door-to-door campaign verification map (AGES, 2016a)

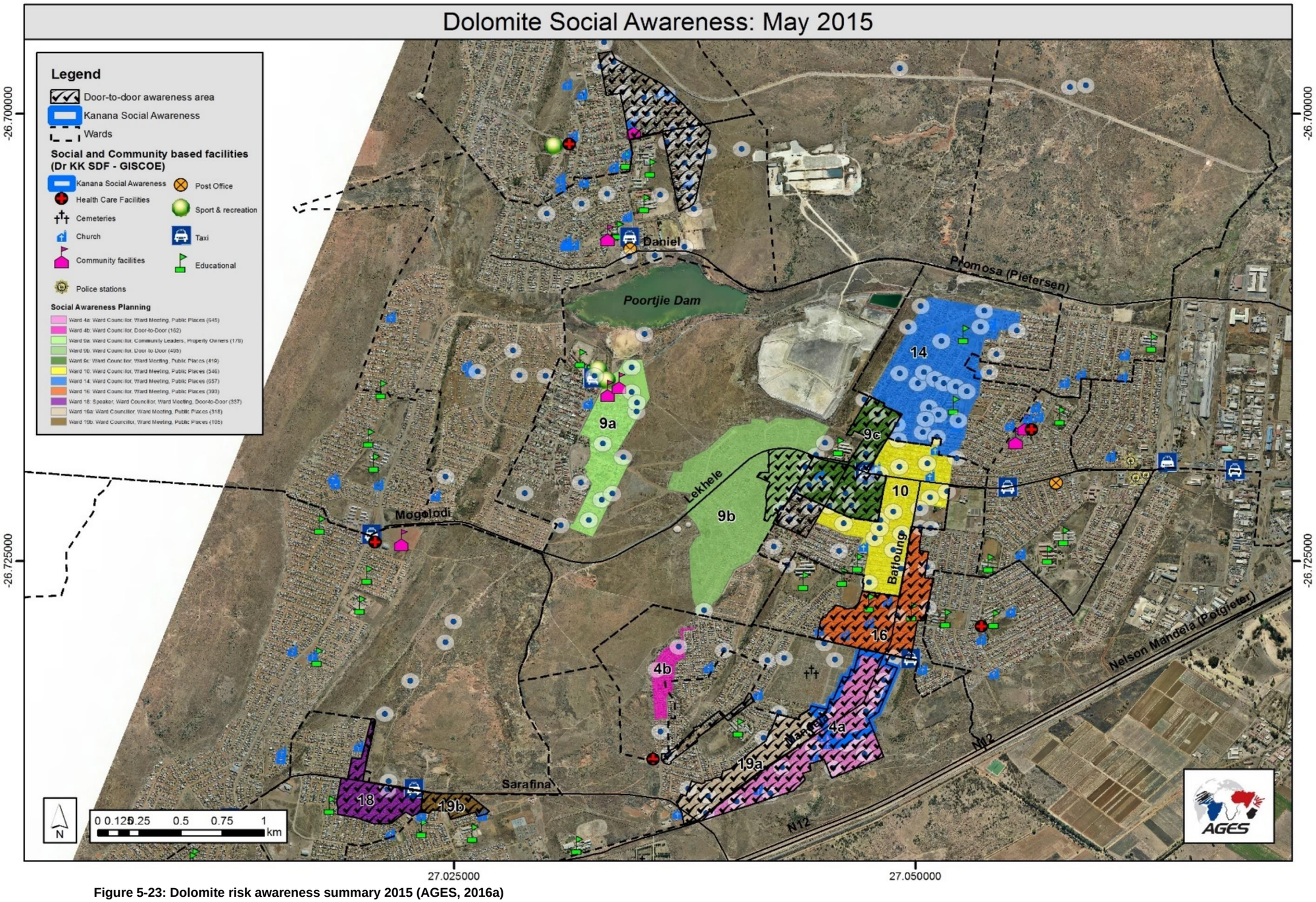


Figure 5-23: Dolomite risk awareness summary 2015 (AGES, 2016a)

5.8.6 Political impasse

During February 2016, by-elections were held in a few wards. This political context delayed the door-to-door campaign as well as all other actions planned for schools. The field had to be cleared for politicians to campaign, and not even the disaster management volunteers could proceed with awareness campaigns. With the completion of the by-elections, the national election was in view and the door-to-door and schools' programme had to be postponed until after the elections.

5.8.7 Schools programme

The importance of school programmes to channel information to households is evident. Due to the political climate and context, the interventions planned by me for this specific period could not proceed. This left the schools programme as the biggest gap in dolomite risk awareness.

However, the worst affected school was visited frequently, and a meeting was convened between the Department of Education, TCC and school management to address critical issues such as the cessation of borehole abstraction activities and monitoring of leaks and cracks.

Risk messages in general try to change behaviour by describing the threat presented when behaviour is not modified (Reynolds & W. Seeger, 2005:45). With the schools programme the focus should not be on creating panic but rather on empowering schools to be vigilant and take an interest in the science of dolomite, as well as the mitigation measures associated with dolomite and sinkholes.

5.8.8 Dolomite ambassadors

In an interview with Wiggill (2016:50), the TCC Human Settlements and Planning Manager indicated his preference for ward councillors to be equipped so that they can in turn serve as a source of risk information for their ward members. This premise is somewhat problematic as ward councillors have a diverse range of political views and represent opposing political factions and alliances, as well as personal and ward agendas linked to housing provision and support base.

Through the workshops and SC meetings, the dolomite ambassadors were defined as students within the community who have been studying environmental sciences and who could be trained to serve as information sources for the affected wards. A number of challenges arose from this endeavour:

- Students were identified as potential candidates with the assistance of the NWU-Potchefstroom campus but only two students fell into this category;
- sustainable remuneration was not available; and

- students were only available for the remainder of their studies.

Due to above-mentioned constraints, the TCC decided to rather request councillors to identify candidates within their wards to be ambassadors. Guidelines for the identification of suitable candidates were provided, as well as agreements concerning the roles and responsibilities of chosen candidates. This process was postponed due to the lack of remuneration incentives for ambassadors, added to time constraints for ward councillors to implement guidelines concerning the appointment of ambassadors.

5.8.9 Research outcomes related to the Dolomite Management Desk

In a study conducted to investigate the effectiveness of the DMD (Wiggill, 2016:53), the affected residents responded as follows with regard to the overall perception of the communication of risk to residents:

- Although affected residents were visited by monitoring teams, they were not empowered to manage the risk and do monitoring;
- there is uncertainty regarding the respective roles and responsibilities of AGES and TCC. This confusion led to expectations that AGES should repair infrastructure;
- the TCC did not follow up on calls to report cracks and leaking infrastructure;
- respondents were not certain about the nature and extent of the risk;
- respondents felt unsafe because of the lack of information from the TCC and ward councillors;
- respondents felt that the TCC does not care about their safety;
- the awareness campaign is effective, and the risk is explained well;
- the consultant was perceived as informed, friendly and helpful;
- the DMD did not keep residents with building plan applications up to date with progress
- the ward councillor was asked to get the consultant to inform the ward, but the ward councillor refused;
- the TCC did not communicate openly about the dolomite risk;
- the TCC did not want to share the findings of the DSI;
- the TCC is not to be trusted to manage the dolomite risk;
- you have to be insistent and badger the TCC to obtain information;
- ward councillors do not want the risk to be revealed as it would damage their power base; and
- residents are frustrated with extended delays and lack of communication.

Wiggill (2016:54) concluded that two-way communication should be established so that affected

residents may be heard and participate in decision-making, and roles and responsibilities should be defined and communicated. She also proposed that feedback by the DMD should be provided without delay to affected residents and the TCC should communicate the dolomite risk clearly and openly and should not allow politics to influence the communication of risk. Wiggill (2016:54) concluded that dolomite risk communication in the TCC should not focus on technical issues only and should not be one-way in nature but should focus on establishing trust relationships and on empowering the community to participate in decision-making. The conclusions of the study by Wiggill (2016) as well as the mitigation measures to address the issues highlighted by the research are summarised in Table 5-4.

Table 5-4:Risk awareness mitigation in response to Wiggill (2016)

Risk Awareness Mitigation in response to Wiggill (2016)		
Action/ Uncertainty/Concern	**Risk Communication Method**	**Mitigation**
TCC and AGES		
There is uncertainty regarding the respective roles and responsibilities of AGES and TCC. This confusion leads to expectations that AGES should repair infrastructure	Media, Door to door, Ward Councillor	Media statement explaining status and way forward
TCC		
TCC does not follow up on calls to report cracks and leaking infrastructure	Workshops for Officials, door to door, leaflets	Workshop Infrastructure held, leaflets with roles and responsibilities and contact channels provided with door to door and all awareness actions
Respondents felt unsafe because of the lack of information from TCC and ward councillors	Media, Door to door, Ward Councillor	Individual sessions with ward councillors
TCC does not care about their safety	Media, Door to door, Ward Councillor	Media statement, article in Tlokwe news, Ward Councillor sessions, door to door focus on proactive stance of TCC and progress
The TCC does not communicate openly about the dolomite risk	Media, Door to door, Ward Councillor	Media statement, article in Tlokwe news, Ward Councillor sessions, door to door focus on proactive stance of TCC and progress
The TCC does not want to promulgate the findings of the AGES DSI.	Media, Door to door, Ward Councillor	Ward Councillor sessions, Planning for Ward Councillor workshop 2
The TCC is not to be trusted to manage the dolomite risk	Media, Door to door, Ward Councillor	Media statement, article in Tlokwe news, Ward Councillor sessions, door to door focus on proactive stance of TCC and progress
Ward Councillors do not want the risk to be revealed as it would damage their power base	Ward Councillor	Individual sessions with ward councillors
The ward councillor was asked to get AGES to inform the ward, but the ward councillor refused	Ward Councillor	Individual sessions with ward councillors
Residents are frustrated with extended delays and lack of communication	Media, Door to door, Ward Councillor	Media statement, article in Tlokwe news, Ward Councillor sessions, door to door focus on proactive stance of TCC and progress
AGES		
AGES does not keep residents with building plan applications up to date with progress	Dolomite Desk, Media, Door to door	Dolomite desk process revisions
AGES was perceived as informed, friendly and helpful	Dolomite Desk.	Affirmation of actions
The AGES awareness campaign is effective and the risk is explained well	Dolomite Desk, Media, Door to door	Affirmation of actions

5.8.10 Approach to communication

Reverting to the guidelines of Aristotle (Muller-De Lange, 2019) regarding rhetoric a training session was conducted, revisiting known principles and acquire some new skills to engage the affected residents. The following steps were explained and practiced:

Step 1: Trust

Ethos centres on the integrity of the source or the speaker. For example, actors in pharmaceutical ads wear lab coats as it makes them seem more intelligent. Ethos is typically established at the beginning of the argument. Your audience has to trust you in order to listen and really hear you. This is why it is sensible to consult with and gain the support of respected figures in the community. In a door-to-door situation, the person conducting the surveys or creating risk awareness would be someone that the community will respect. The person's authority will be increased by factors such as age, communication skills and how well they are trained or educated about the matter.

Step 2: Making sense

This pertains directly to the content of the speech. Logos is the logic of the argument. Not only does the point of the argument have to be logical, but it has to be explained in such a manner that the entire argument is clearly presented. Each explanation and piece of information should have a purpose in your communication to maintain clarity. Logos can be compared to a ladder where each step should be there in order to get your audience to the place you need them to be.

Step 3: Emotional appeal

Pathos is audience-centred. It concerns emotional appeal. The speaker should identify something within that audience that he or she can employ in their address to illustrate its relevance to the audience specifically. This is why it can be useful to employ the use of religious leaders within the community: not only do they possess the necessary ethos, but they can connect and communicate with the community on a more spiritual and emotional level. Pathos is usually employed more to the end of the argument, because the speaker wants to eventually have the audience reach a point where they are entirely aware of the significance of the issue itself, as well as their own importance regarding the issue (Muller-De Lange, 2019).

Employing these techniques, the team was ready and enthusiastic to start fieldwork again.

5.8.11 Dolomite desk revisited

The level of sophistication of the DMD was developed to the extent that building plan turnover adhered strictly to the timeframes set. Acknowledging the input from stakeholders and considering how to handle inquiries about the progress of building plan applications, the DMD developed an SMS (text message) notification system to update applicants as their application proceeds through every stage. This is a powerful way to create awareness of dolomite processes and relieve the uncertainty experienced by affected residents. As part of the awareness sessions, this feature is explained alongside the building plan process.

5.8.12 Dolomite documentary

Since the inception of dolomite risk awareness actions, the plan was to develop a documentary that would serve as an awareness tool at schools while appealing to a variety of stakeholders. The benefit of a scripted documentary was that the pitfalls of personal communication, such as non-verbal cues and nervousness that can create mistrust, can be avoided (Fischhoff, 1995:142). The first draft of the script was developed by geo-environmental specialists and it was re-scripted by me to form a storyline with simplified concepts. The script was subsequently submitted to community members to provide input as to the efficacy and clarity of terminology and concepts employed. This script was edited to become a frame-by-frame documentary script.

In an effort to create more accessible material, the live shots were interspersed with 2D and 3D animation. The first part of the dolomite documentary covered the basic questions about dolomite:

- What is dolomite?
- Where does it occur?
- How are sinkholes formed?
- What must I do?

The second part of the documentary was planned for external stakeholders such as service providers and affected municipalities. It contains interviews with an engineering geologist and a senior housing and planning official, providing recommendations pertaining to the DRMS and requirements for development on dolomitic land.

The dolomite animation character was based on the geologist acting in the live footage. The appeal this character had on pilot audiences as well as the real-life responses to the geologist presenter during fieldwork awareness interventions, served as motivation to me for using this character for continuity in the successive leaflets. The learners at schools could not only identify with the character, but also with someone from their own community who has been educated and

in turn aims to capacitate them.

5.8.13 External stakeholders

Presentations on the risk of dolomite and sinkholes were made by the technical team on district and provincial levels with the focus on disaster management, human settlements planning and environmental departments. Presentations were also made to environmental forums and the NHBRC. The NWU was involved in the project, providing inputs on all aspects of the DRMS. Seven post-graduate studies have been conducted on various aspects of the project, leading to academic awareness of the risks associated with dolomite and sinkholes. The dolomite risk awareness team represented by me also had a seat and standing presentation on both the TCC Disaster Management Advisory Forum and the Dr Kenneth Kaunda District Municipality Disaster Management Advisory Forum.

5.8.14 Monitoring

Monitoring was either routine with the intention to measure fluctuation in subsurface water levels, to survey crack monitors installed in high risk residences, or in response to the logging of an event or concern from the community. During the initial visit of a geologist to a residence that has been affected by dolomite, risk awareness efforts were included, and the homeowner was provided with risk awareness leaflets.

5.8.15 Dolomite roles and responsibilities

Risk communication messages should include responsibilities that can provide affected stakeholders with a perception of control (Reynolds & W. Seeger, 2005:45). A fact sheet with the roles and responsibilities of homeowners living in dolomitic areas was drafted by me and attached to all correspondence for homeowners. The fact sheet was also printed on the reverse side of risk awareness leaflets. Due to the vulnerability of the community, it was decided to convert this information into a cartoon leaflet (Fig. 5-24).

This leaflet was the final risk awareness action to be considered part of the DRMS C1. Unfortunately, the project was halted due to financial and political constraints.

5.8.16 Overview

The cessation of the DRMS is very unfortunate, but the willingness of the TCC to invest in the most comprehensive research, monitoring and awareness programme on high risk dolomitic areas in order to mitigate anthropogenic risk undertaken in South Africa is commendable. As far as could be ascertained through research, it is also the most comprehensive dolomite risk

mitigation campaign globally. It has set a foundation to build on, but politics may not be allowed to continue to place lives at risk.

For the time being, the only monitoring and management is done on a regional level by the Dr Kenneth Kaunda Municipality, and no risk awareness actions are in place to mitigate the anthropogenic risks for vulnerable communities living in low-cost housing on dolomite.

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Figure 5-24: Dolomite Risk Awareness leaflet 3

5.9 Conceptual framework for a dolomite awareness plan

As one of the research outcomes from the TCC case study, I analysed the case study in order to evaluate each action according to its applicability and efficacy as part of the mitigation of anthropogenic risk (Muller, 2017). Figure 5-25 represents this framework.

This framework recognises the three critical elements in the realisation of a DRCS, namely the message content, the entity or person that conveys the message and the receiver of this message in the form of affected stakeholders. The framework establishes an iterative flow between message formulation, messenger entity and stakeholders within a socio-economic and political context, which influences the implementation of the phases of the DRMS and the chosen risk awareness actions that act as enablers for the mitigation of the risk associated with dolomite and sinkholes.

The final outcome of the case study research combined with the results of the focus group conducted as last action for the DRMS provided a guideline for consultants or other stakeholders involved in the management and mitigation of anthropogenic risk by creating awareness or risk strategies.

The one element that was mentioned but not elucidated in the framework and therefore underestimated to a large extent, was the socio-economic and political context in which these interventions are applied. As the outcomes of the case study and emergent theory from the focus group at the conclusion of the study illustrate, it is in effect this context that should be defined in combination with the emergent data from the focus group discussion. This necessitates the creation of criteria to supplement and guide the implementation of the framework in vulnerable communities in order to successfully mitigate the anthropogenic risk.

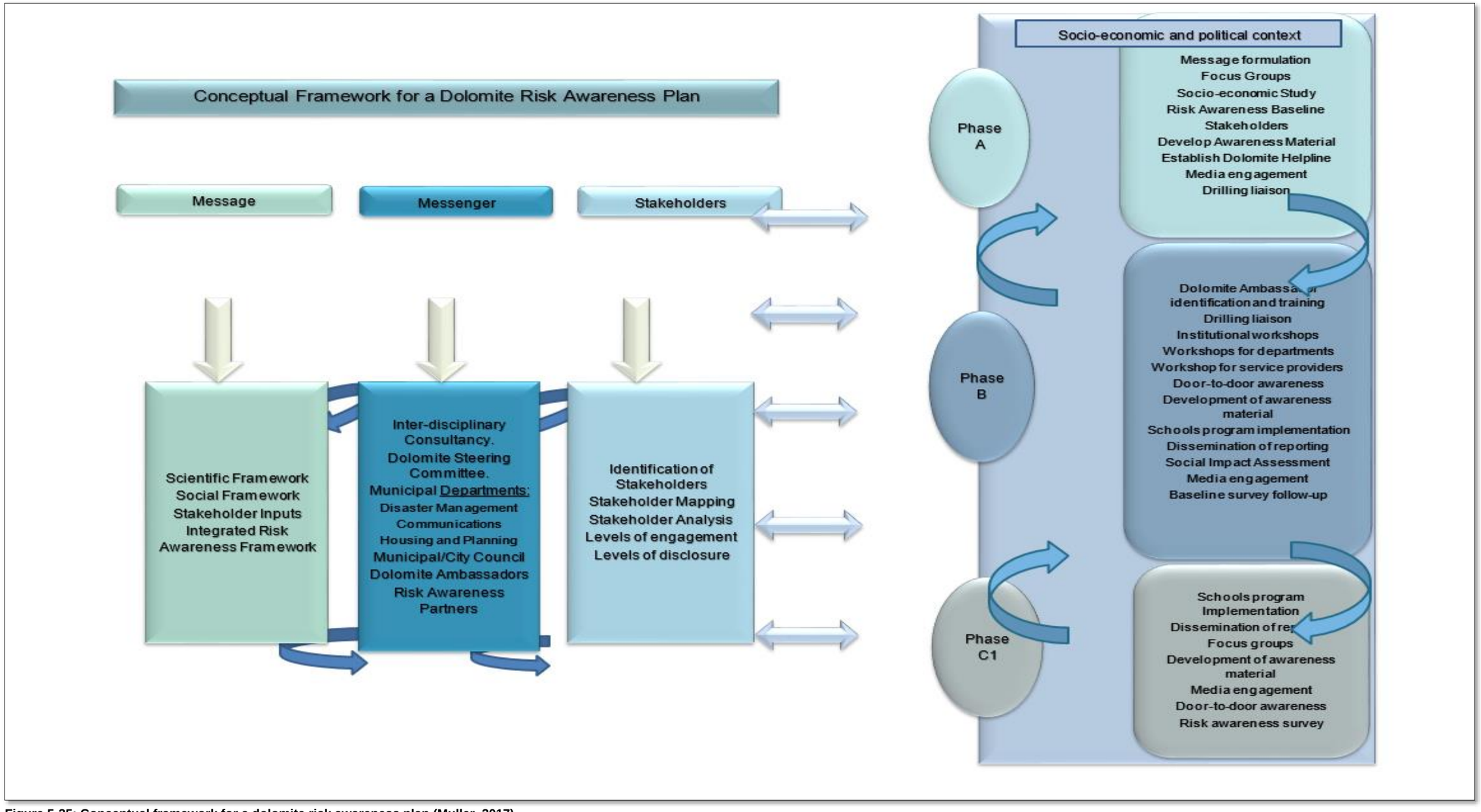


Figure 5-25: Conceptual framework for a dolomite risk awareness plan (Muller, 2017)

5.10 Focus group

Shortly before the conclusion of the project, the risk awareness team decided to address the issue of a sudden unwillingness to participate in risk mitigation interventions. The residents, while living on the edge of a sinkhole, would not accept awareness materials or speak to consultants. Contractors appointed to build RDP started delivering building material to the most dangerous area in Ikageng housing the most vulnerable residents.

Due to the extreme politicising of the dolomite, the decision was made to conduct a focus group discussion in order to reflect on the previous mitigation and to prepare for a strategy going forward. Sampling from the affected residents had the potential to ignite a spark and turn unwanted attention to the issue. The focus group comprised spiritual leaders representing the high-risk dolomitic areas with low-cost housing structures.

The focus group was conducted as a semi-structured discussion to facilitate the flow of the conversation. The methodology of coding the transcript is described in Chapter 2 of this thesis. This type of thematic analysis was chosen to identify salient themes that could be identified from the concepts, narratives and insights of the participants.

Figure 5-26 illustrates the open coding done throughout the project lifecycle. This primarily represents the issues that arose from the different interventions. The concepts that guided the mitigation actions were grouped into categories. These categories were applied to the project documentation as specified in Chapter 2.

The coded concepts are marked with the symbol D to illustrate the density of relationships with other identified codes. The G symbol indicates how grounded the codes are in transcripts or documentation. The emergent theory was applied during the different steps of the risk mitigation. As a final step, the project minutes, reports and other documents were coded with the main categories identified through the open coding until saturation.

The focus group coding was done in vivo. The codes generated from this process were also grouped into categories with the density indicated on the code. In the focus group the concepts are grounded in the direct quotations from the participants.

The first coding was done, followed by the process of re-assessing the project interventions and mitigation measures, incorporating additional theory and reframing the mitigation of anthropogenic factors in low-cost housing areas. The second coding was done only after a two-year period. The second coding did not significantly affect the initial codes, but yielded more nuanced insights into the focus group transcript and its multi-faceted context, which led to

additional codes being generated. Theses codes sparked emergent categories.

The interpretation of the case study open coding is discussed briefly, accentuating the insightful discrepancies between this coding and the emergent categories generated by means of the focus group.

The emergent categories are analysed in terms of the effect they have on the context and approach in mitigating the anthropogenic risk of low-cost housing on dolomitic ground. In Chapter 6, the outcomes of this process are represented in the form of criteria that can be used to guide future mitigation of anthropogenic risk where vulnerable residents are involved.

5.11 TCC open coding

The categories emerging from the open coding represents the focus of the mitigation throughout the project. It seems as if what was set out in the DRMS and DRCC is represented in the inputs and outcomes of our stakeholder engagement and interventions.

We planned for the stakeholders to be the highest priority; the residents exposed to the risk of dolomite in low-cost housing. The DRCC was the key to addressing the mitigation of anthropogenic risk factors. The research and application of emerging research ensured that all the boxes could be ticked that could be applied to the basic tenets of creating awareness in order to mitigate environmental risk.

Despite applying researched interventions and iteratively incorporated feedback into the strategy, the situation arose of residents at risk due to the impasse reached. Table 5-6 summarises the principle open codes and the categories stemming from them are visualised in Figure 5-26. After establishing the TCC focus group categories, this comparison was made to illustrate the variation in outcomes.

The categories that show agreement are those concerned with dolomite management and the TCC, as well as dolomite risk awareness. It must be accentuated that this agreement exists only in terms of relative importance, density and the extent to which they are grounded. The content shows inconsistencies in data and perceptions of the official versus the informal narratives and context. These categories and the emergent categories are discussed in section 5.10.2.

Table 5-5: Open coding and In vivo categories (own interpretation)

Open coding	Grounded	Case study Categories	Focus group Categories
Stakeholders	214	Tlokwe City Council Low-cost housing Community participation Stakeholders Anthropogenic factors	Dolomite Risk Management Mitigation of anthropogenic risk Local politics Narratives Indigenous knowledge Risk Communication Vulnerability
Dolomite	187		
Awareness	180		
Residents	76		
TCC	70		
Sinkhole	41		
Media	37		
Management	37		
Building	34		
Mitigation	27		
Municipality	24		
Infrastructure	25		

The categories embedded in the data, the summary of the research outcomes and the theoretical grounding of the emergent themes are discussed in section 5.12 to 5.17 by following the Atlas.ti 8 network maps illustrating the various core categories and their associated high density and grounded codes. Only the emergent categories are supported by theoretical insights.

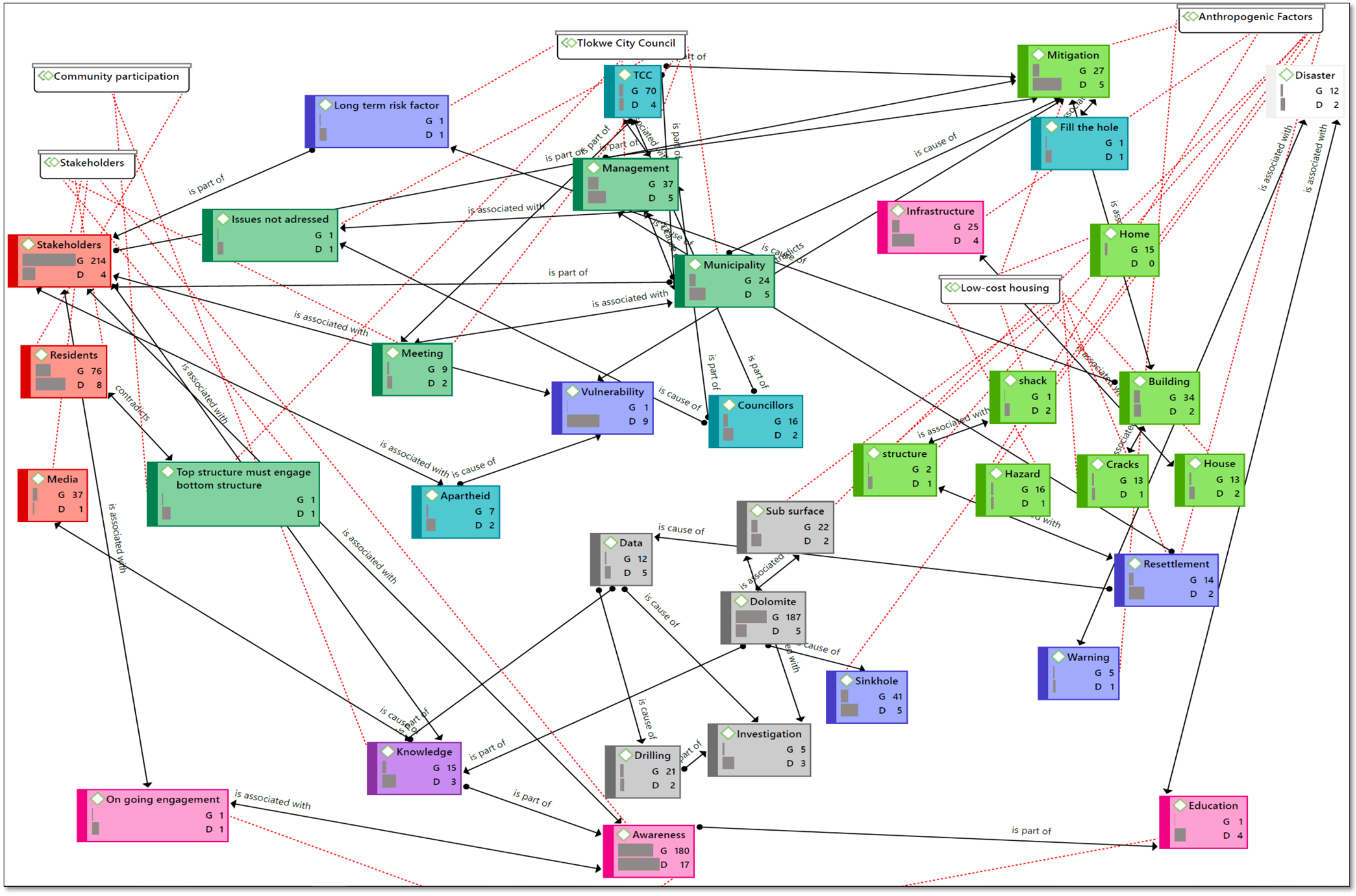


Figure 5-26: TCC open coding (Atlas.ti 8 generated)

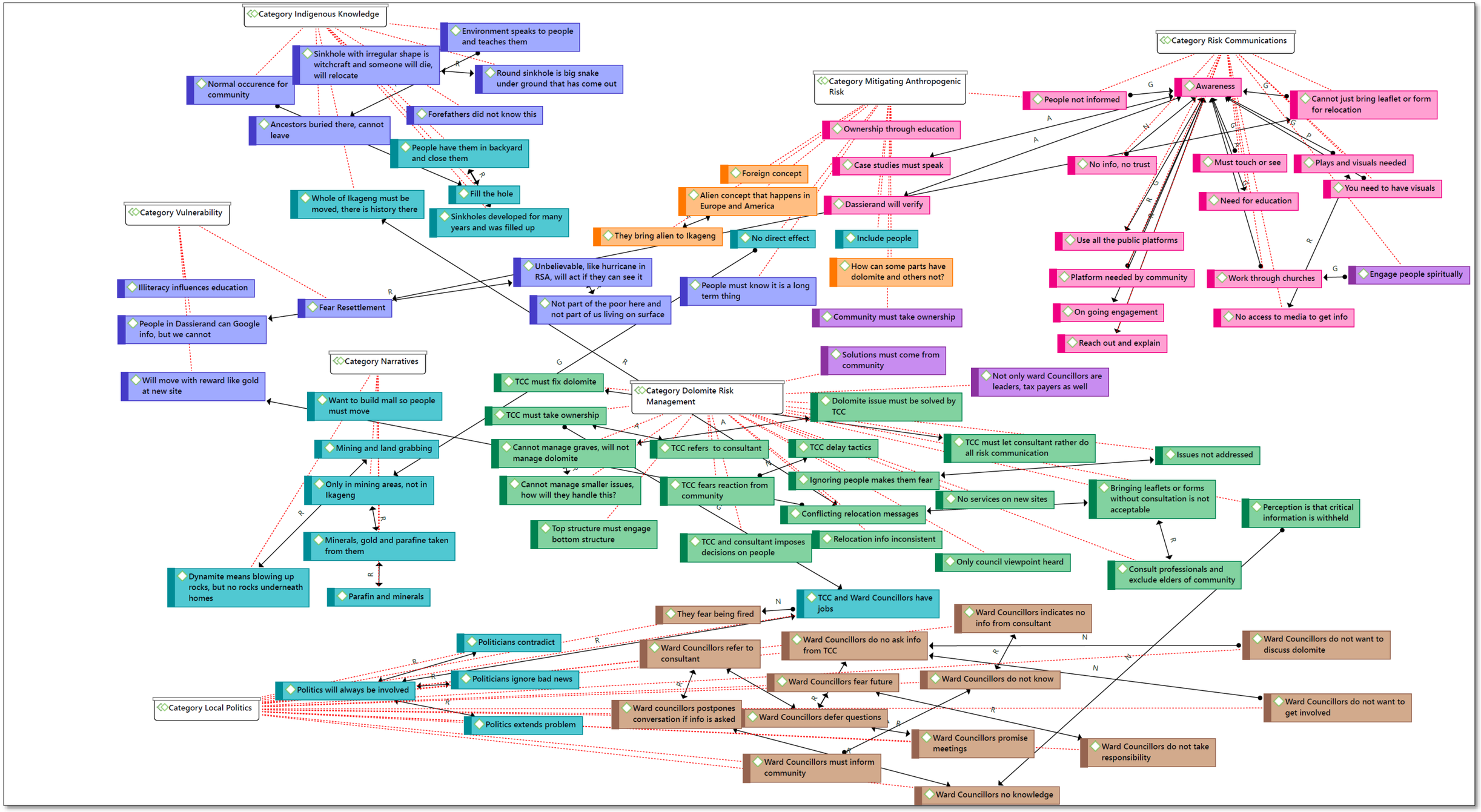


Figure 5-27: TCC focus group codes (Atlas.ti 8 generated)

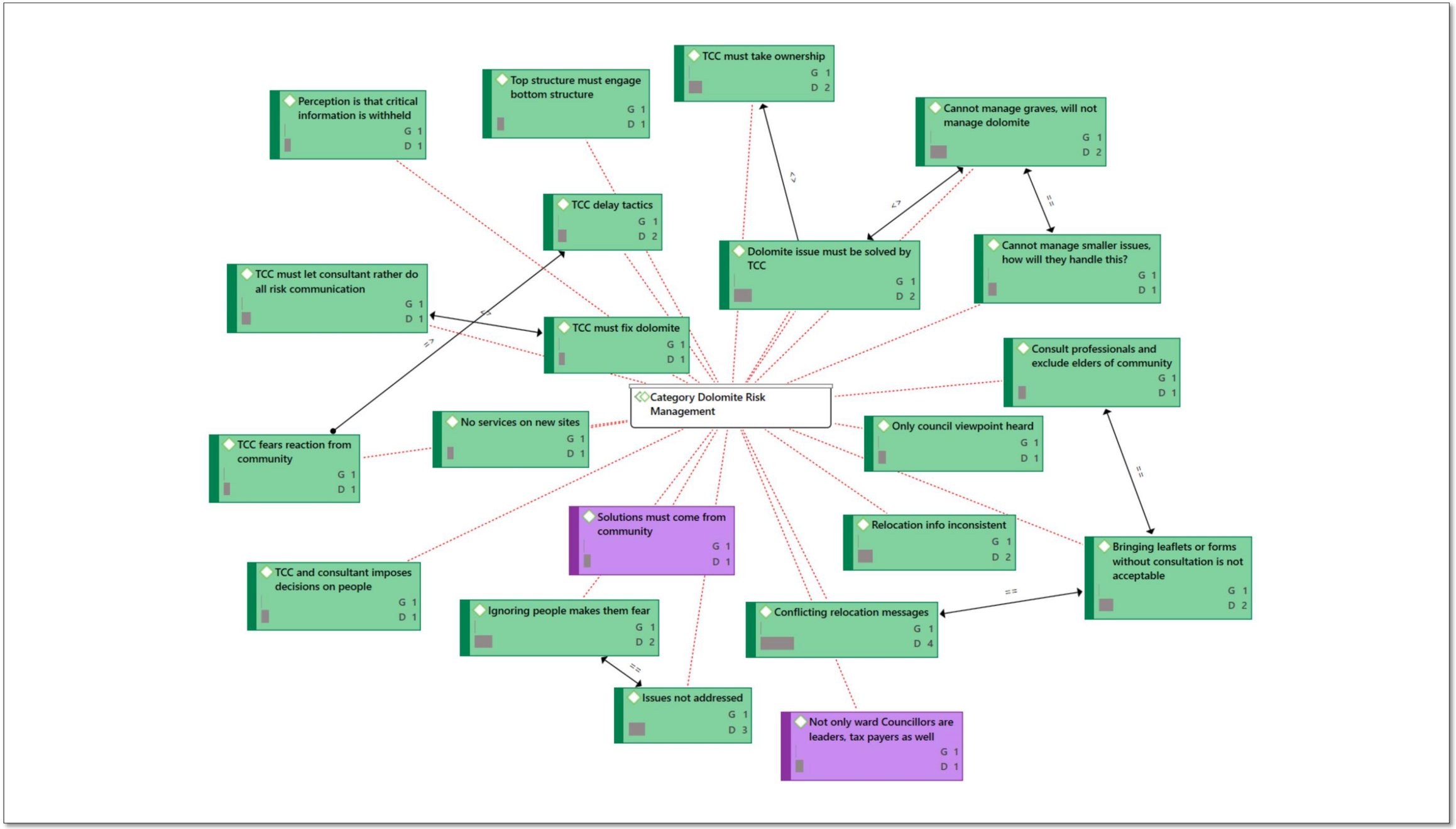


Figure 5-28: Category DRM (Atlas.ti 8 generated)

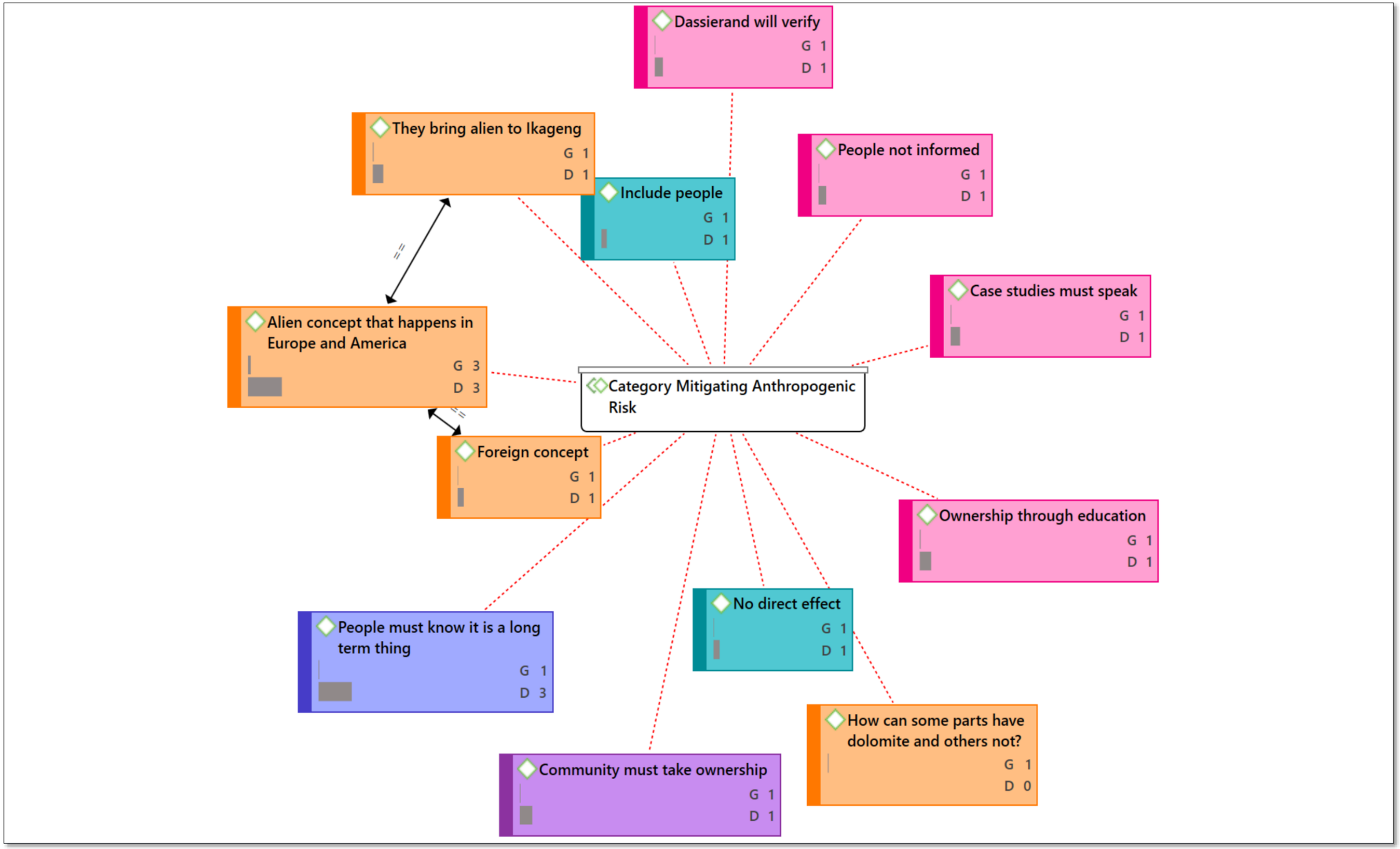


Figure 5-29: Category mitigating anthropogenic risk (Atlas.ti 8 generated)

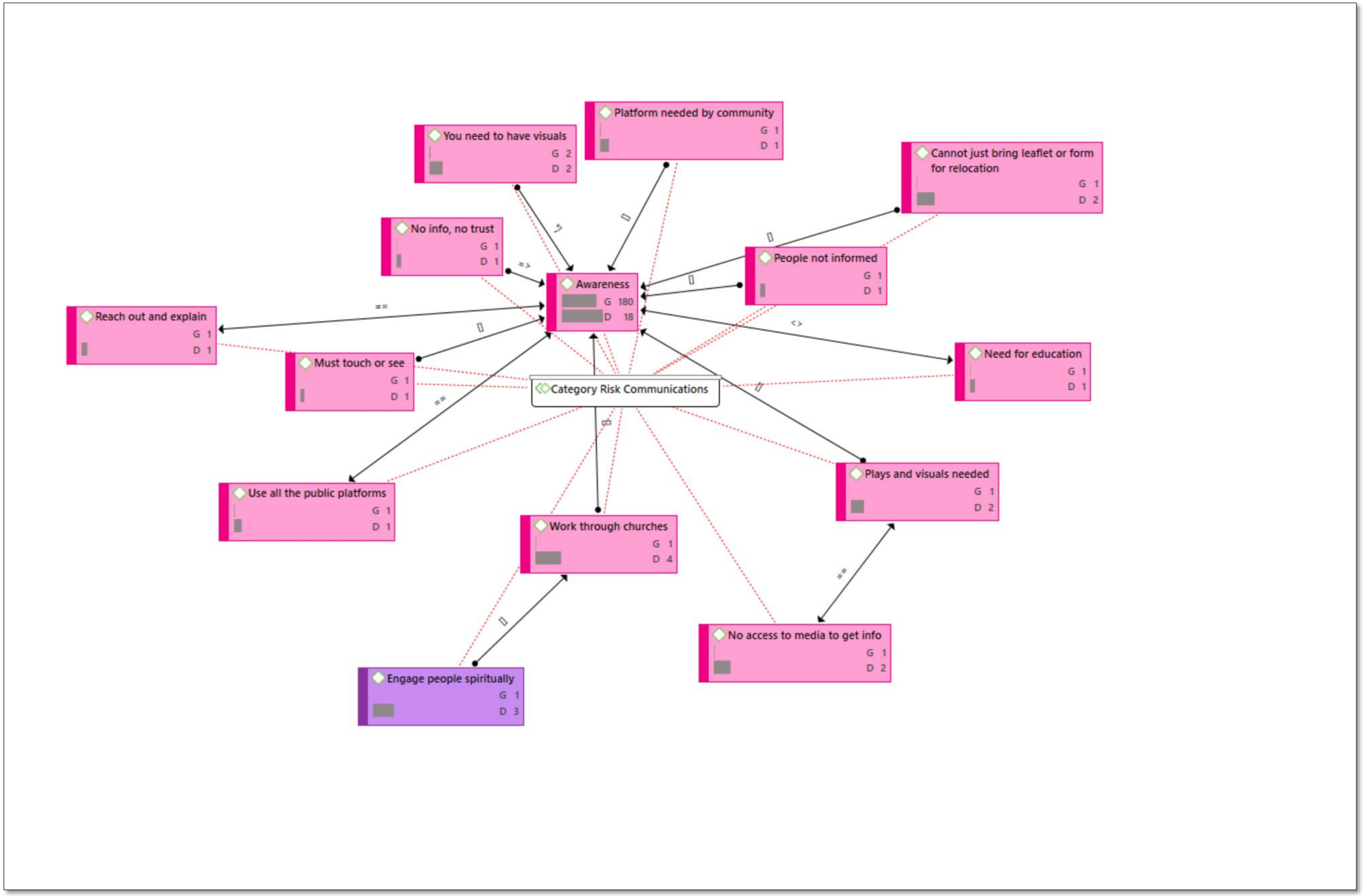


Figure 5-30: Category risk communication (Atlas.ti 8 generated)

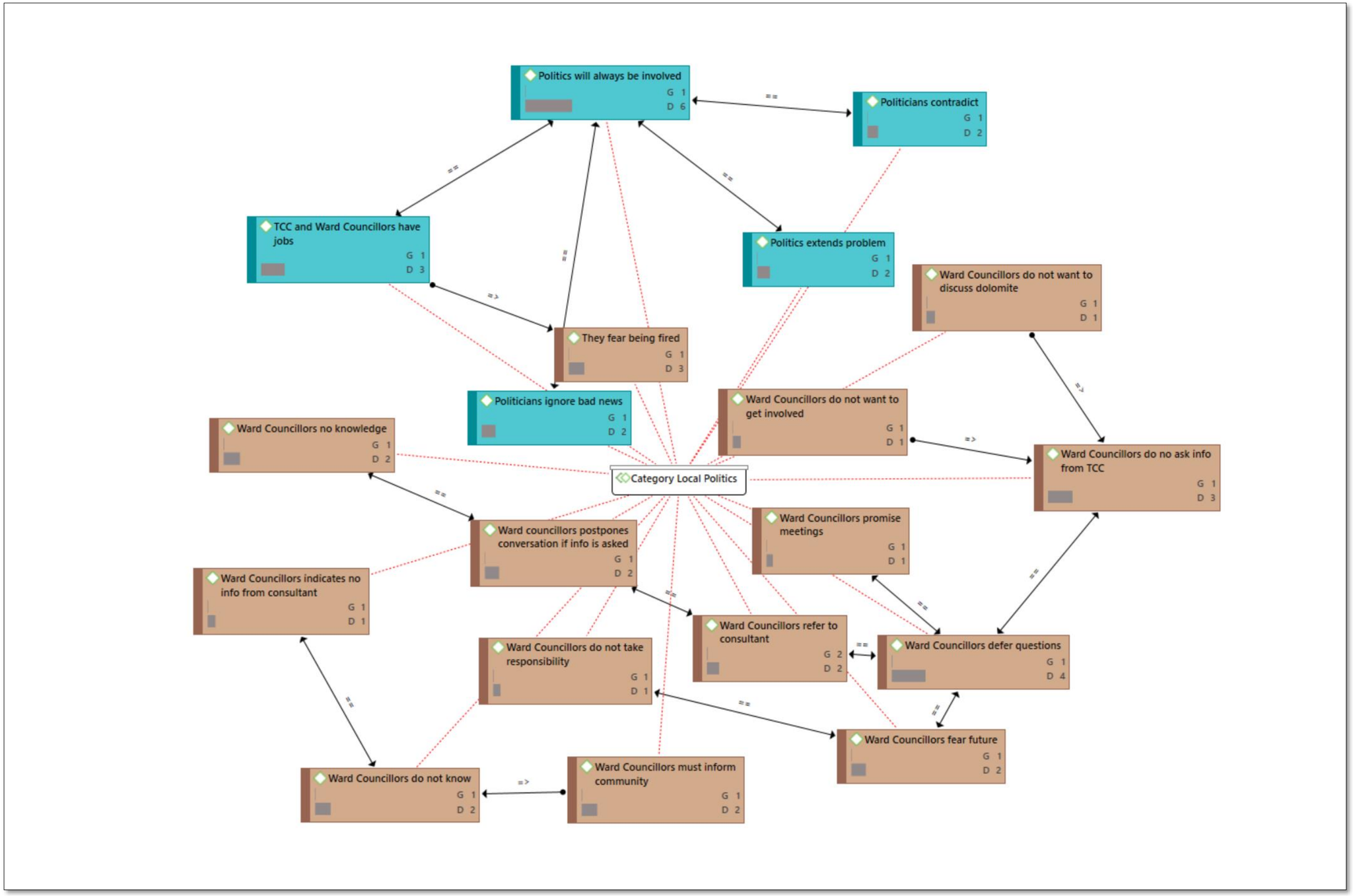


Figure 5-31 Category local politics (Atlas.ti 8 generated)

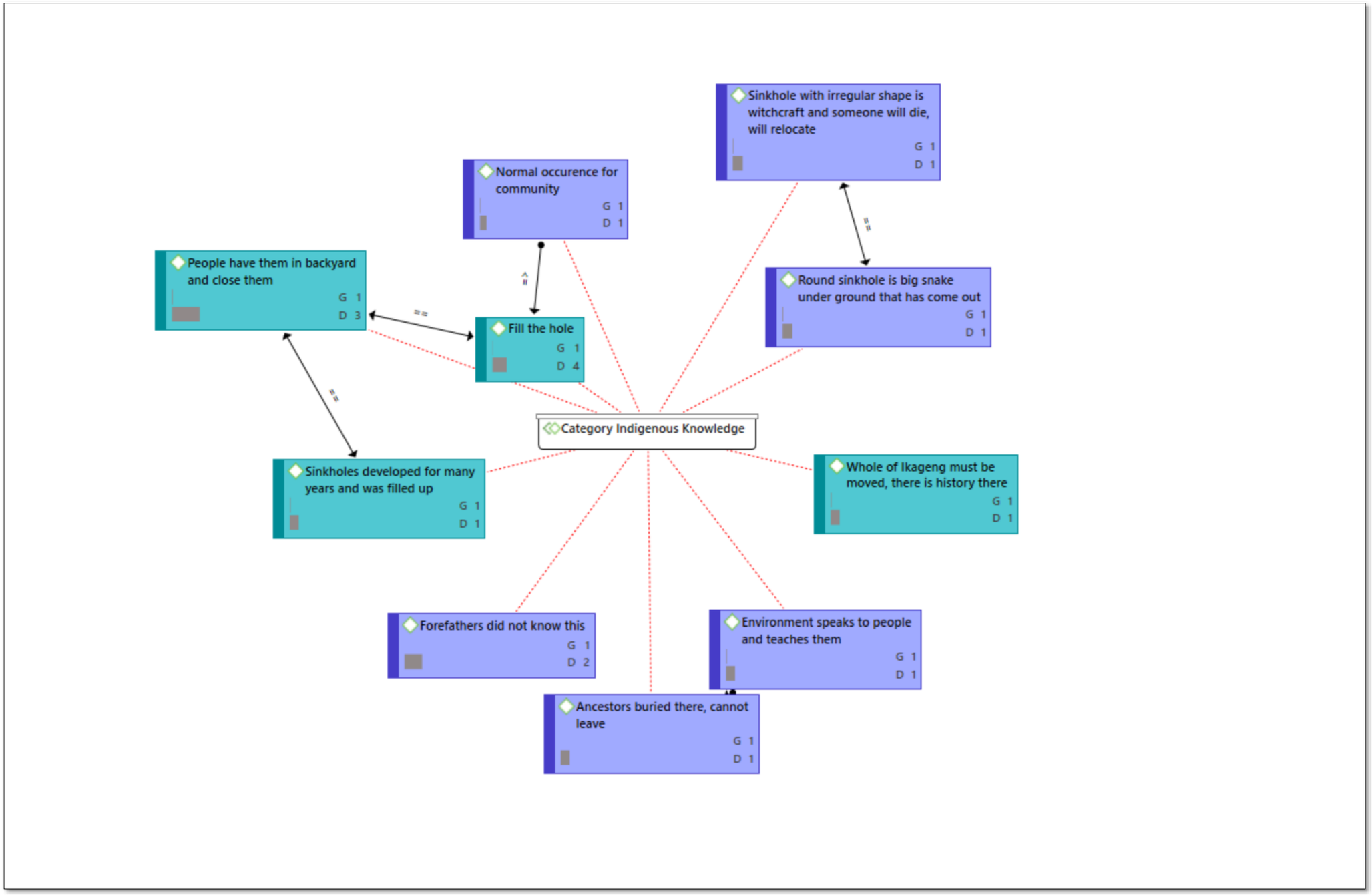


Figure 5-32: Category indigenous knowledge (Atlas.ti 8 generated)

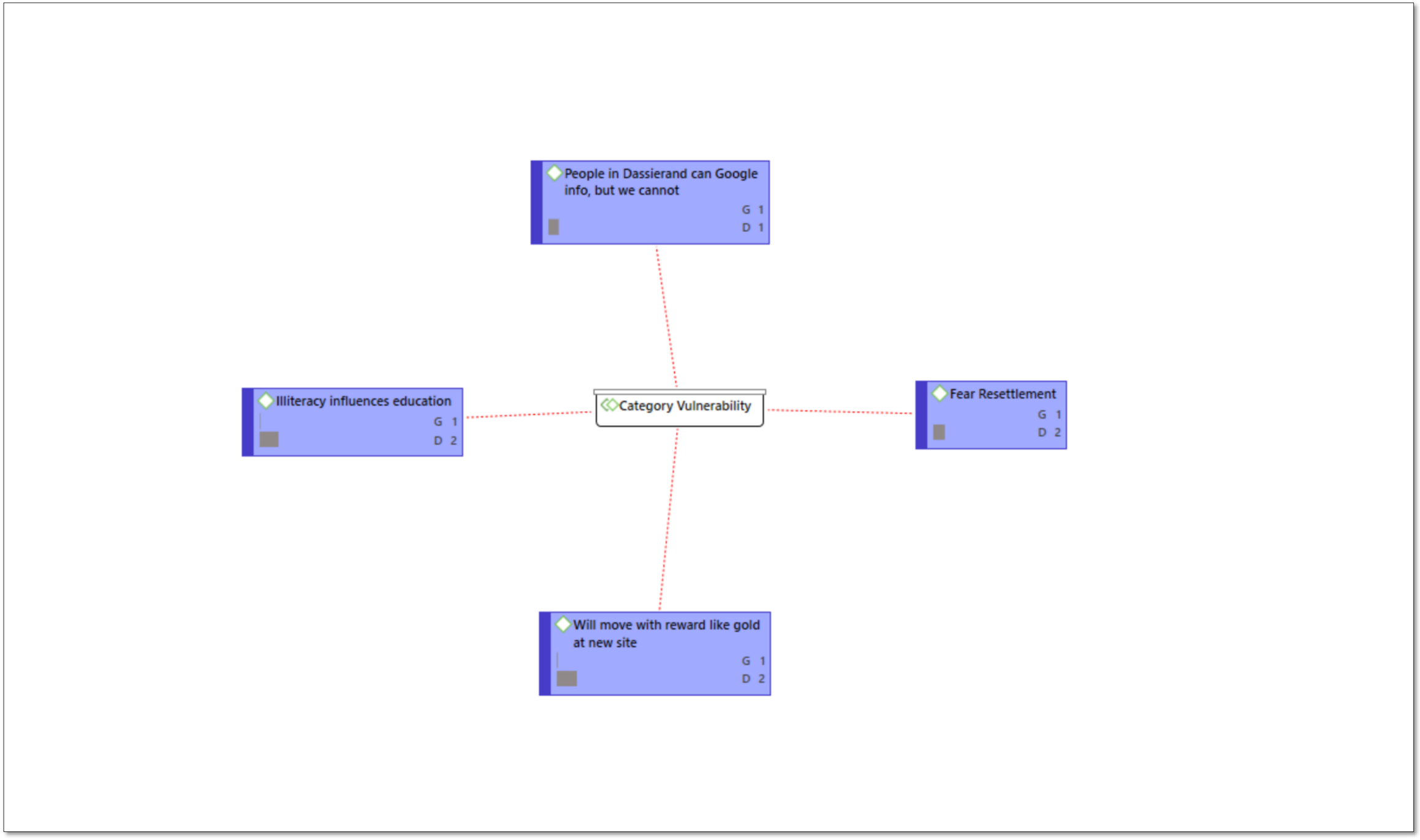


Figure 5-33: Category vulnerability (Atlas.ti 8 generated)

5.12 Category: Dolomite risk management

- The fact that issues are not addressed does nothing to mitigate the risk. It has the over-arching effect that residents live in fear.
- Residents do not feel empowered. They are already vulnerable and the perception that the TCC and consultants impose decisions on them emphasises this. The ward councillors are privy to all the information, but it is not disseminated to their wards.
- The elders of the community are not consulted, only specialists and consultants, while it is the community's lives and future.
- All these actions, or rather the absence of involvement and participation, leaves residents feeling disenfranchised.
- To mitigate risk, residents would like be part of the solution and not just part of the perceived problem.

5.13 Category: Mitigating anthropogenic risk

- Despite the attempts to create awareness in order to mitigate the anthropogenic risk, participants still feel it is foreign concept and something that happens in countries such as the USA.
- A recurring theme that surfaced throughout the project and again here, is that it is difficult to understand that my structure is on hazardous dolomite and I have to consider anthropogenic mitigation measures, which may include resettlement, but at the end of my street people live safely. It seems like an inconsistency.
- Both the participants' vulnerability and ownership of the issue were raised. They feel that people in Dassierand, which is a part of the township where the homes are permanent and more affluent, residents can just Google the term "dolomite" and understand what it entails. In comparison to their situation, where they do not have access to media, internet and other resources.

5.14 Category dolomite risk communication

- The core messages focus on the need for more visual elements in the awareness campaign.
- The request to use churches for awareness projects and the need for spiritual support may be a categorical variable due to the focus group selection. The involvement in local vulnerable communities has also made me aware of how important their spiritual lives and

church are in their daily life. It is also used by other organisations for spreading important messages.

- Inclusion and consultation form a theme resonating through all the categories, along with the need for information and platforms to discuss this hugely important topic.

5.15 Category local politics

- Most of these narratives centre on the roles and responsibilities of ward councillors.
- They have security, namely jobs and income, and are not as vulnerable as the affected residents in their communities.
- The perception is that ward councillors either do not have sufficient information, or they ignore the problematic issues and defer to consultants in order to sidestep their responsibility.
- When the government first conceived of housing distribution in its 1994 Housing White paper, it went to great pains to emphasise the impartiality of its programme. Against the backdrop of “the spectre of Zimbabwe” (Hart 2002:305, 2006:984) just next door, a case of redistribution rife with nepotism, not to mention the contentious debates over land reform during the transition at home (Greenberg 2003; Hall 2004; Levin and Weiner 1996; Walker 2003), the transitional team did what it could to reduce the risk of local politicians using free homes as a means of securing political loyalty.
- Faction forming continues to govern the landscape of politics and local politicians take advantage of the vulnerability of the community at risk as they may have vested interests in housing projects continuing

5.16 Category indigenous knowledge

- Dolomite is not something new as their ancestors have known about it all along, and for them sinkholes around Ikageng is a known issue.
- They believe sinkholes to be a way in which the environment has been speaking to them and educating them.
- Resettlement is for many not an option as they do not want to leave the graves of their forefathers.
- The size of sinkholes is an indication of the force by which it was formed.
- Their roots are in Ikageng, they do not want to be separated from their community and have to move.
- Indigenous knowledge may not be deemed” scientific,” but is filled with rich experience (Thinda, 2009:2).

- Land in African culture is seen as a place where ancestors live and it has spiritual connections (Kolobe, 2011:4). Resettling people is not just about mitigation of risk but much more, as forefathers are attached to an area through generations. This creates a very deep sense of belonging.
- The social-ecological systems theory states that residents would experience a greater sense of belonging because of their cultural and ethnic roots.
- The relocations of the apartheid era have become part of the lived experience and any possibility of it recurring stirs deep seated fear and mistrust.

5.17 Category vulnerability

- I have included this as a separate category, although it is not populated densely in the focus group results.
- The dire straits of the participant's circumstances are highlighted by the fact that they will move for a reward and the repetition of the fear for resettlement.
- The following table illustrates the dimensions of vulnerability of residents living in low-income housing as I have come to understand them throughout the project lifecycle:
- The topic of vulnerability did not directly emerge from the focus group discussion, but it is not a label any person will naturally assign to themselves. The allusions to almost all the other factors correspond with the dimensions of vulnerability.

5.18 Overview

The open and in vivo coding reaffirmed the implementation of the DRCS, but both the reaction of the community and the emergent categories gleaned from the focus group discussion contributed to identifying the gaps in the implementation of the Framework for Dolomite Risk Communication.

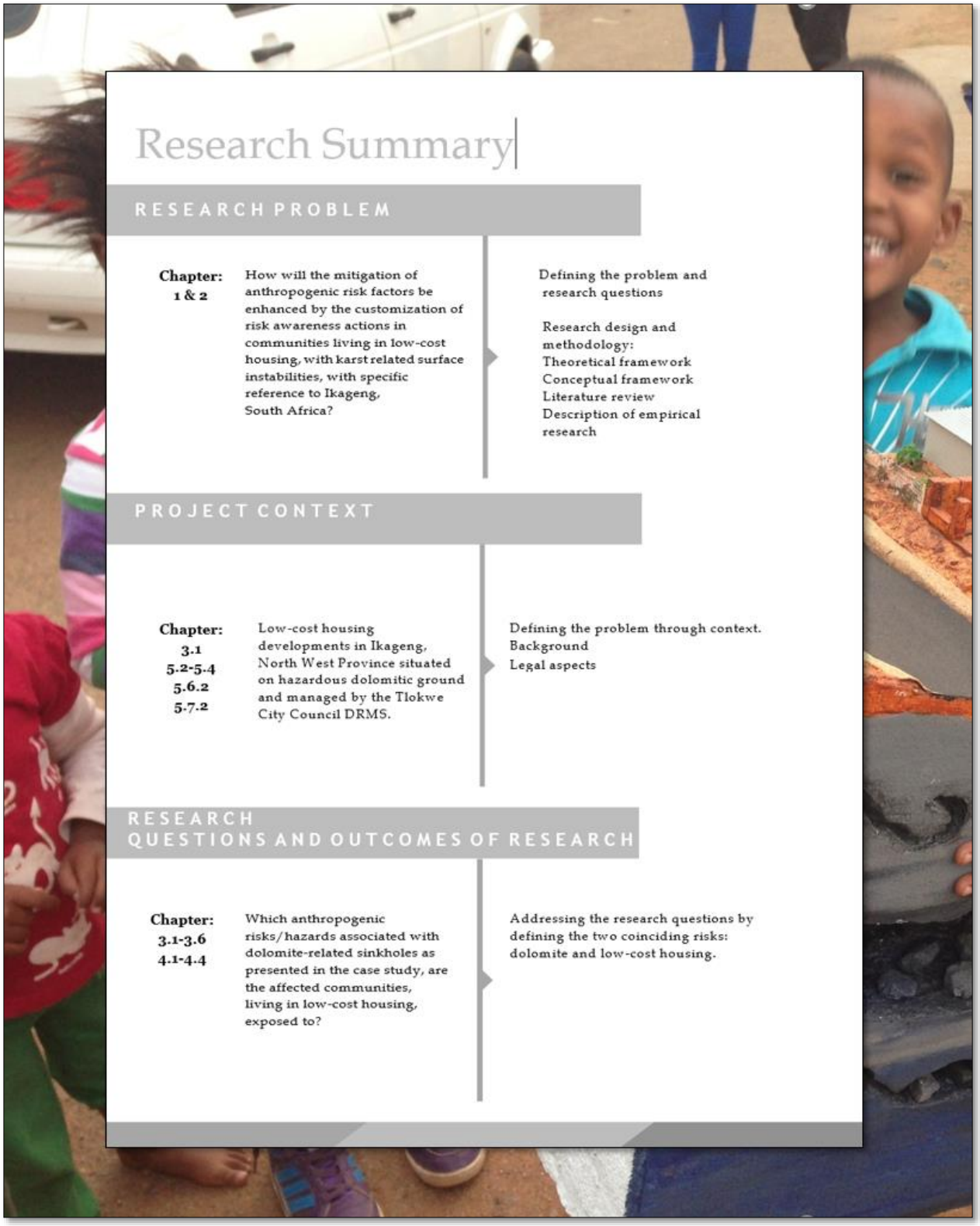
In the final chapter, the conclusions on the research outcomes, fieldwork experience and case study observations and community inputs are provided. Thereafter the criteria recommended for a more nuanced and customised approach to the planning and execution of risk communication protocols to mitigate the risk of anthropogenic factors in low-cost housing are presented.

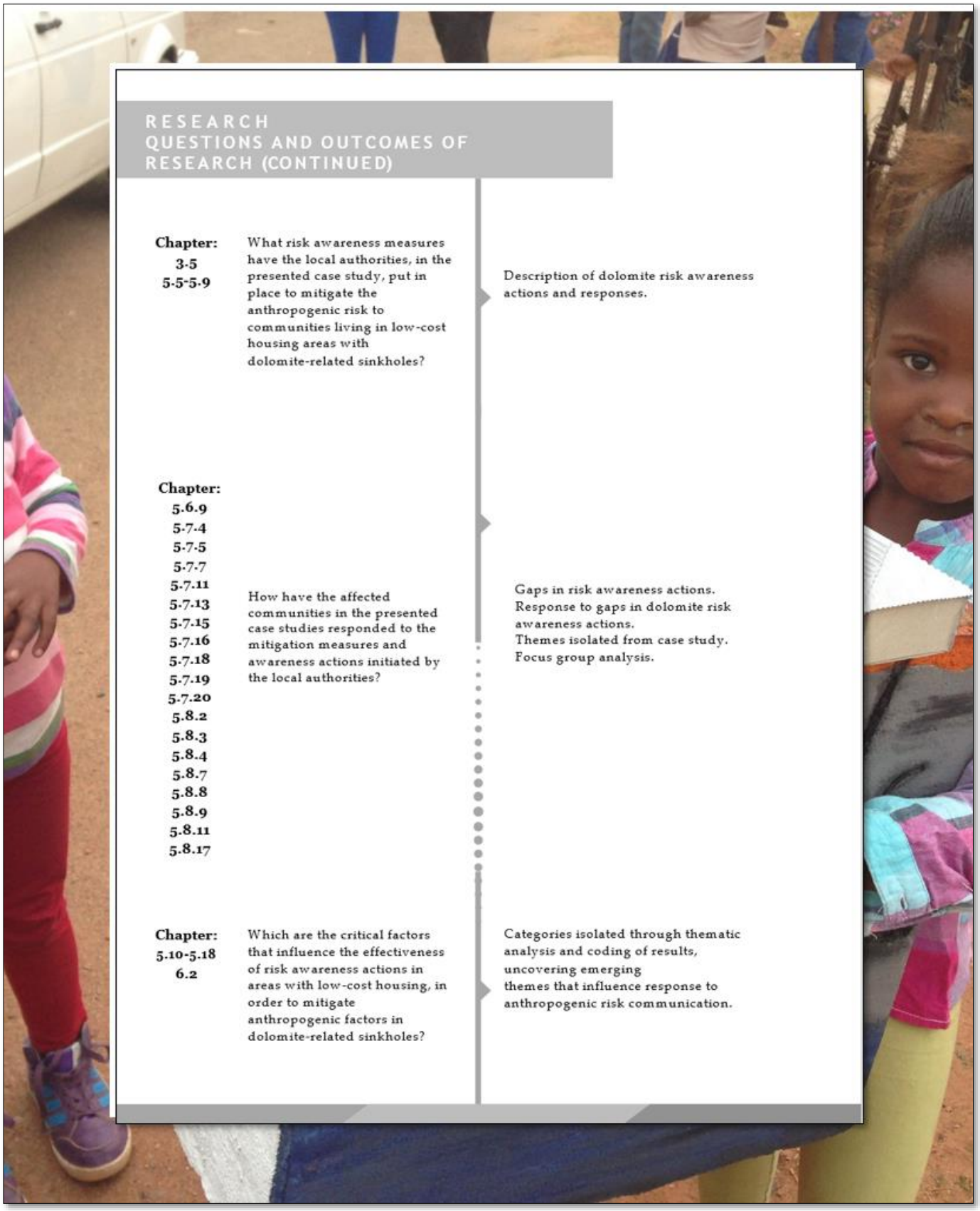
CHAPTER 6: WHEN THE FACTS ARE NOT ENOUGH

6.1 Overview of the study

The summary below outlines the response of this thesis to the research questions and indicates where in the study it is located:

Table 6-1: Research summary





RESEARCH QUESTIONS AND OUTCOMES OF RESEARCH (CONTINUED)

Chapter: 3.5 5.5-5.9	What risk awareness measures have the local authorities, in the presented case study, put in place to mitigate the anthropogenic risk to communities living in low-cost housing areas with dolomite-related sinkholes?	Description of dolomite risk awareness actions and responses.
Chapter: 5.6.9 5.7.4 5.7.5 5.7.7 5.7.11 5.7.13 5.7.15 5.7.16 5.7.18 5.7.19 5.7.20 5.8.2 5.8.3 5.8.4 5.8.7 5.8.8 5.8.9 5.8.11 5.8.17	How have the affected communities in the presented case studies responded to the mitigation measures and awareness actions initiated by the local authorities?	Gaps in risk awareness actions. Response to gaps in dolomite risk awareness actions. Themes isolated from case study. Focus group analysis.
Chapter: 5.10-5.18 6.2	Which are the critical factors that influence the effectiveness of risk awareness actions in areas with low-cost housing, in order to mitigate anthropogenic factors in dolomite-related sinkholes?	Categories isolated through thematic analysis and coding of results, uncovering emerging themes that influence response to anthropogenic risk communication.



6.2 Research conclusions

6.2.1 Anthropogenic factors will not go away, and low-cost housing is here to stay

Globally, the greenhouse effect that leads to global warming and climate change will impact karst terrains as well. The increase in frequency of extreme events was predicted by the Intergovernmental Panel on Climate Change as early as 2007 (IPCC 2007) (Day, 2010:143). Drought or very rainy seasons as a result of climate change may affect the water levels in aquifers and lead to sinkholes forming.

Zoning in on our country, we know that funding will not be readily available. The COVID-19 pandemic that swept through the world in 2020 has ravished economies and created backlogs in service delivery. The expectation is that this will translate into decreased funding for maintenance and new infrastructure projects. It will also affect the delivery of houses and the proliferation of backyard dwellings, and illegal and informal settlements will grow even more.

Infrastructure in all developments, and especially RDP developments, are getting older. We cannot guarantee the quality of infrastructure and can't be sure that infrastructure presumed to be dolomite compliant are indeed compliant. These factors do not bode well for the failure of wet

surfaces and resulting ingress of water. Poor quality building practices in low-cost developments will continue to exacerbate the anthropogenic effects on dolomite.

In response to research question 1, Chapter 3 described the anthropogenic risk and the scientific framework with respect to dolomite and sinkholes. The chapter also discussed how the risk can be mitigated. Low-cost housing and the repercussions of building it on hazardous dolomite was described in Chapter 4. The picture painted by these two phenomena coinciding shows a risk that should be addressed expeditiously as the anthropogenic risk is escalating at an alarming rate.

6.2.2 Dolomite risk management and communication

In order to address the risk described in Chapter 3 and 4, Chapter 5 addresses research question 2 and 3 as it describes the legislative and management aspects put in place to mitigate the risk. Part of this is the mitigation of risk through risk communication actions. It describes the process that unfolded through the various project lifecycles to convey the message of how every stakeholder can mitigate the anthropogenic factors while living on dolomite. The complications associated with these interventions and the reaction of affected residents have been described. The project process and outcomes were studied and coded to see whether there were recurring themes that would act as clues to identify the key elements.

As the reactions sometimes confounded scientists, a focus group was conducted to position the DRCS strategy. The outcomes of the focus group and the case study were coded and grouped into categories. The outcomes of these networks are discussed briefly at the end of Chapter 5. The emergent categories provided insights which were theorised and that led to an additional literature study.

What became clear in the communication of risk is that local government will have to step up to the plate and provide the leadership entrusted to them by their wards. Research by the Institute of Security Studies (ISS 2014:15) indicates that the protests in many communities across South Africa may be traced back to the lack of leadership, specifically among ward councillors. Respondents considered ward councillors' leadership traits and their responsibilities in service delivery (Mbandlwa & Mishi, 2020:2).

Ward councillors must be representative of their community and be advocates for the rights of their community. Councillors should also be able to speak freely about issues affecting their communities and be able to make informed decisions (James & Cox, 2007:22; Mbandlwa & Mishi, 2020:3). They should be political representatives, leaders, community advocates and knowledge champions. If this could become a reality, the management of anthropogenic risk could be significantly improved.

The hope is that the criteria created will provide the much-needed context and a protocol to follow when considering the formulation of a risk communication strategy or any risk awareness campaign in low-cost housing areas under threat of hazardous dolomite.

6.2.3 Science in service of society

The science–society interface can be seen as science in service of society, which includes the way in which scientific knowledge is disseminated to society (Turton *et al.*, 2006:377). The residents living in low-cost housing have been described in terms of their vulnerability. The science behind the occurrence of dolomite as expounded in Chapter 3 of this thesis forms the basis of all the risk communication messages that are sent through a variety of channels.

The people most affected by the risks are also the same group who have so much capacity to mitigate the risk to their lives and livelihoods by applying the measures that may address the problems. However, to be empowered they must really understand the risk and accept it as a threat.

On the one hand the message must be made visual and clear to meet every stakeholder at their level of understanding. This is why the focus group repeatedly referred to the visual and tactile aspects of understanding dolomite. The other side of the coin is that the dissemination of scientific information must not be restricted to a few in privileged positions. We should not make the mistake of underestimating people just because they may be labelled as vulnerable. Being vulnerable does not entail that you meet every requirement of the category of vulnerability.

It has been my experience that stakeholders enjoy perusing maps and processing the scientific underpinning of the anthropogenic risk presented to them. They may not have had access to an education, but they have the capacity to process complicated information. By offering a variety of knowledge products that address different levels of engagement, we may experience greater effectivity in risk communication.

The research into the stability of dolomite and the anthropogenic risks associated with dolomite in low-cost housing is mostly financed by public funding. Heath and Constantinou (2015:505) estimate that the cost of DSI for housing developments adds up to USD 5000 to the cost of each new house.

The data and results should be disseminated to the residents affected by the situation. The lack of transparency and exclusion creates suspicion, which fans mistrust in the integrity of the results.

There is a general tendency for municipalities and consultants to keep dolomite-related information confidential and not sharing best practices. This is seemingly underpinned by

professional and income-generating principles. The other more disconcerting motive is the repression of information to conceal hazard classes and risk to the benefit of property values and planned housing developments. It is understandable that some critical information interpreted incorrectly could be alarmist, but if the risk to lives is the focus of our research, we have an ethical imperative to work together and use science to serve society.

6.2.4 Indigenous knowledge

The leaves, animals, even stones say much, and they show much to any prepared to see and hear (Lartey, 2013:116).

The African worldview incorporates the concepts of being and existing and does not perceive nature as a separate entity, but rather as overflowing with spiritual significance (Mbiti, 1977:55; Gottlieb & Olupona, 2009:264; Schuman *et al.*, 2018). Therefore, all material phenomena such as soil or water has agency. Nature is in the spiritual and not only the physical realm and is experienced holistically together with the powers that control the world (Schuman *et al.*, 2018:2). This idea represents the basic belief of animism.

The solutions put forth for mitigating the risk are derived from the views of scientists backed up by data and deductions derived from the data. Historically, these positivist traditions with scientific rigour and reliability and proof derived from data experience difficulty with accommodating context-rich data from outside theses protocols and criteria (Green, 2013:13). The criticism of scientific community is also that indigenous knowledge is rooted in belief and is in opposition to reason.

The people who are affected by dolomite and sinkholes and have lived with this hazard may have a perspective on the mitigation of the risk based on indigenous knowledge transmitted through narratives over generations. The only problematic area is that the custodians of these narratives do not necessarily document it. This means the original intent could be lost. Muller (2020) alludes to the fact that the narratives of the snake under the ground or a spirit coming from the sinkhole could have originated from a concerned society trying to keep children from going near these dangerous holes. With the original meaning lost, it could again be connected to the spirit world.

Another variable is that with global climate change and the levels of neglect of maintenance has overburdened the former pristine environment with a variety of stabilising grasses and other plants. The indigenous knowledge may no longer be applicable or sufficient in mitigating the anthropogenic risk.

Historically it has been problematic to combine the two worlds of indigenous knowledge and

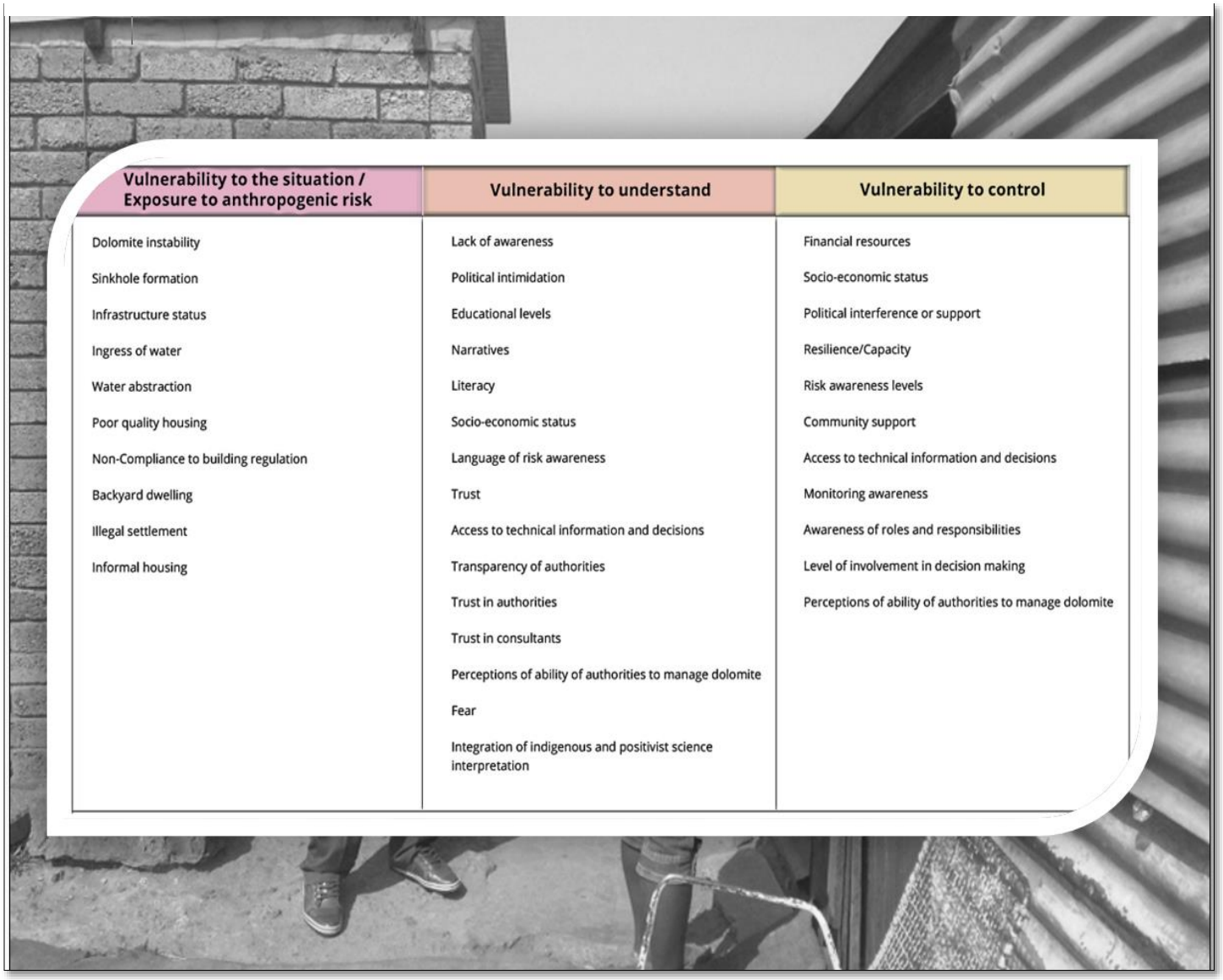
traditional science. Instead of perpetuating this dichotomy, we should rather focus on creating knowledge commons not steeped in suspicion but inviting and accepting (Green, 2013:14). It is less about consensus and more about recognising the prospect of plurality and the vitalities of each other's insights.

6.2.5 The dimensions of vulnerability

Vulnerability is a key construct in the mitigation of anthropogenic risk and is both cause and outcome of the low-cost phenomenon. The research conducted in this thesis reaffirms the success of mitigation measures such as risk communication. It should be customised to suit the vulnerability of the affected community. The following table is a summary of the dimensions of vulnerability identified in terms of exposure to risk, control and comprehension of the meaning and significance of the mitigating measures proposed by risk communications interventions.

The vulnerability to the situation points to the vulnerability of a community to the dolomitic hazard, but also to the anthropogenic factors that influence the risk posed by dolomite. Some stakeholder groupings will be more vulnerable than others because of the poor structural quality of their homes or ignorance of the effects of non-compliance to building regulations. Dolomite risk awareness actions should consider this vulnerability by acting promptly and providing as much information as possible for them to reduce some of the vulnerability to anthropogenic factors.

Table 6-2: Dimensions of vulnerability



Vulnerability to the situation / Exposure to anthropogenic risk	Vulnerability to understand	Vulnerability to control
Dolomite instability	Lack of awareness	Financial resources
Sinkhole formation	Political intimidation	Socio-economic status
Infrastructure status	Educational levels	Political interference or support
Ingress of water	Narratives	Resilience/Capacity
Water abstraction	Literacy	Risk awareness levels
Poor quality housing	Socio-economic status	Community support
Non-Compliance to building regulation	Language of risk awareness	Access to technical information and decisions
Backyard dwelling	Trust	Monitoring awareness
Illegal settlement	Access to technical information and decisions	Awareness of roles and responsibilities
Informal housing	Transparency of authorities	Level of involvement in decision making
	Trust in authorities	Perceptions of ability of authorities to manage dolomite
	Trust in consultants	
	Perceptions of ability of authorities to manage dolomite	
	Fear	
	Integration of indigenous and positivist science interpretation	

- Naturally, the antidote to vulnerability is growing resilience and building capacity. Project teams cannot eradicate poverty and illiteracy in order to reduce vulnerability while creating risk awareness and mitigating anthropogenic risk.
- The dimensions of vulnerability can be incorporated into the progression of vulnerability model (Wisner *et al.*, 2004), where root causes and dynamic pressures coupled with unsafe environments assert pressure from all sides and lead to a so-called nutcracker effect (Thinda, 2009:91). By closing the gap with anthropogenic risk awareness, the vulnerable community is empowered to take ownership of the risk.

6.2.6 The politics of housing

The densification of urban areas has led to the fast-tracking of housing developments. This means that houses are provided that in many instances are not well constructed, leading to an increased vulnerability for its inhabitants. In the broader context, the fast-tracking of housing projects leads to inaccuracies in the administration process that should determine who is eligible for social housing and who gets erven/stands. This also leaves the community with residual anger and frustration amongst each other and towards leadership structures from local government.

When the government first conceived of housing distribution in its 1994 Housing White Paper, it went to great pains to emphasise the impartiality of its programme.

In a document meant to transform the landscape of housing, the Department of Human Settlements promised that in addition to the 4.3 million subsidies and houses provided, they would have delivered 1.5 million more by 2019. If they had succeeded no person in South Africa would be homeless (Pillay & Sayeed, 2017:375). Instead of this, corruption on all levels of government and in the private sector has led to vulnerable people living in shacks in informal and sometimes illegal settlements.

The conundrum our country faces is that the elected representatives of the people are sometimes part of the reason that they do not receive housing. Corruption takes many forms, especially with reference to two issues. The first is housing waiting lists. People may be on waiting list anything from 10 to 30 years, only to find out others have jumped the queue for a substantial fee paid to an official. The lists are not transparent, so you never know precisely how long you will have to wait.

Secondly, tenders for RDP developments are riddled with corruption. As the appointments are sub-contracted, it provides a further complication. It is a possible source of income to the community. In some cases, the community members do not have access to their ward councillors as they do not live in the community they serve. Due to the lack of participatory structures in housing projects, residents are kept in the dark as to what the status of RDP projects are, coupled with the reality that community politics exceed formal representation (Kitchin, 2017:98; Levenson, 2018:124) or who has vested interests in projects. The only persons close enough to government are councillors and politicians, which leaves no choice but to accept their narratives and place their hope in their promises.

The aspects that touch on low-cost housing and mitigation through risk awareness, and intersects with the vulnerability of the community, are:

- The provision of sub-standard housing which presents an anthropogenic risk for the failure of wet infrastructure and subsequent ingress of water;
- the backlog of housing to the poorest of the poor, which leaves them with no other option than to either live in an illegal, informal settlement or be a backyard dweller. The implications are the escalation of anthropogenic risk. Table 4-1 illustrates the amplification of these anthropogenic risks among vulnerable people living on hazardous dolomitic ground;
- the communication of risk is thwarted and undermined by politicians who may have reason to benefit from housing projects and who will be deprived of an opportunity for corruption-associated income if the project does not proceed. They engage in the denial of the existence of dolomite and place the local municipality or consultants under suspicion;
- the final scenario, which also coincides with housing, involves the election of ward councillors or any election for that matter. Should a councillor want to be re-elected or be elected, the provision of housing as part of service delivery is of paramount importance. The same principles apply for general elections. Resettlement is also a hugely unpopular prospect. If the councillor can give assurances that it will be prevented it is to benefit of the councillor. They benefit from saying that the holes can just be filled up or that there is no such thing as dolomite.

It is by no means implied that all councillors or politicians act corruptly. The study merely draws broad lines along which some complications of low-cost housing developments and their vulnerable inhabitants living on hazardous dolomitic ground can be viewed when they do not receive the critical information they need to take ownership of mitigating their risk. Municipalities are as powerful and effective as the effectiveness of elected leadership (Mbandlwa & Mishi, 2020:3).

6.3 Criteria for the mitigation of anthropogenic risk factors in low-cost housing developments on dolomite

This research aimed to address the mitigation of anthropogenic factors in low-cost housing on dolomite within the context of inequalities, financial and socio-political challenges within local municipalities, and the extreme vulnerability of residents living in low-cost developments. In response to research question 5 and based on the outcomes of research question 4, addressed in Chapter 5, the following criteria were created:

6.3.1 Criterion 1

A social impact assessment (SIA) should be conducted before any other actions or interventions are planned. This will provide the necessary context to ascertain the following:

- Who are the stakeholders that should be engaged?
- What are the levels of vulnerability that must be considered?
- What are the salient narratives prevalent in the community?
- What mitigation measures must be implemented to reduce vulnerability or to empower stakeholders to be receptive to risk communication?
- Are there red flags such as political and service delivery issues that pre-exist?
- What does the demographic and community data look like?
- What historical issues have left the community with a collective hurt or residual feelings of distrust and anger?
- What enablers in the community can assist with implementation of risk awareness actions and the monitoring of anthropogenic factors e.g. NGOs and churches.

Table 6-2 summarises the categories of information that can be collected from a SIA.

Table 6-3: Social assessment variables (Adapted from Barbour, 2007) (Kruger, 2020:122)

Category	Social Assessment Variables
Population Characteristics	*Refers to population changes (size and density); ethnic and racial distribution and composition; influx and outflow of temporary workers; presence of seasonal or leisure residents; and relocation of families / individuals / communities.*
Community and Institutional arrangements	*Size, structure and level of organization of local government; local / regional / national linkages; historical and present patterns of employment and income characteristics; industrial diversification; characteristics of voluntary associations; interest group activity; and employment equity.*
Political and social resources	*Includes the distribution of power and authority; the interested and affected parties (IAPs); the identification of key stakeholders; leadership capabilities; conflict between long term / permanent residents and newcomers; presence of outside agencies; and inter-organisational cooperation.*
Individual and family changes	*Factors disrupting the daily living and movement patterns of people; attitudes towards policy / projects; perceptions of risks, health and safety; displacement / relocation concerns; residential stability; change in leisure opportunities; introduction of new social classes; changes in family structures and social networks; trust in social and political institutions; and concerns about social well-being.*
Community resources	*Changing natural resource and land use patterns; changes in community infrastructure and services; changes for indigenous people and religious subcultures; and threats to historical, cultural and archaeological resources.*

6.3.2 Criterion 2

The scientific framework should be aligned with indigenous knowledge and pre-existing inputs from the community.

- The process should start with a sensitivity to hegemony[19]. Reflexivity on the side of all team members is needed to mitigate this issue throughout the process.
- Green (2013:16) calls for an ecology of knowledge encompassing tolerance, recognition and respect between scientific outcomes and indigenous knowledge.
- Initial focus groups, especially with older community members, can provide inputs and become part of the knowledge base informing the DRMS and DRCS.

6.3.3 Criterion 3

The political context should be considered one of the key variables of the successful planning and implementation of any mitigating strategy.

- The political landscape of the area at risk must not only be surveyed as part of the stakeholder mapping and analysis, but as the most important of the criteria proposed.
- Without alignment with community politics the research outcomes and community consultations cannot be implemented and will continue to contribute to mitigation of risk.

6.3.4 Criterion 4

All actions, whether technical research or risk communication, should be reframed by community engagement, consultation and two-way communication.

- Transparency and engagement with the community is not an aspect to consider. It is the first question to ask before any action is set in motion.
- Communication platforms identified by the community should be prioritised.
- In an effort to facilitate communication, social justice and equality, the team may consider the inclusion of an ally[20].
- Research findings should not be separated from its community context (Stoecker, 2012:3). This will mean that large amounts of money and time will be spent on investigations that do not capacitate the community or reduce their risk.

6.3.5 Criterion 5

The project team should be multi-faceted in order to meet the community in the spectrum of their diversity and culture.

- First language proficiency

[19] Hegemony refers to the social, cultural, economic an ideological narrative influence by dominant groups (Ravitch & Carl, 2019:12).

[20] An ally is an advocate for social justice and equality and usually part of a privileged group (Johnson & Parry, 2016:72)

- Older people to interact with traditional segments of community as it is not perceived as acceptable for younger people to tell older people what to do.
- Gender representation
- Technical experts as any inaccuracies may lead to confusion and distrust
- Communication experts to assist with message design

6.3.6 Criterion 6

Enter this endeavour with absolute respect, humility and acknowledgement of your own privilege.

- A scientist is not the only owner and purveyor of knowledge, imparting it to the vulnerable.
- Placing yourself in their situation is impossible, but an approximation of what they are experiencing will suffice in creating empathy. Be a fellow traveller on the journey that will lead to understanding and accepting the reality of the hazard they are exposed to and the adherence to the mitigating measures that will reduce their exposure to the anthropogenic risk of dolomite and sinkholes.

6.3.7 Criterion 7

Ethical conduct towards the community and the client as well as the overarching management of dolomite in South Africa and worldwide is essential.

- By sharing best practice and creating communities of risk awareness expertise, the most effective and attainable strategies can be formulated and applied.
- There should never be a conflict of interest between a client and the affected community when risk mitigation is conducted transparently and inclusively by all stakeholders involved.

6.4 Integrated risk mitigation model

To enrich the conceptual framework proposed in Chapter 5, a revised framework functioning in a space created by the criteria proposed in conclusion to this thesis, was created. When applying the principles to each context and community, the interventions can be customised and enhanced to address the mitigation of anthropogenic factors in low-cost residential developments on dolomite in a more sustainable and effective way.

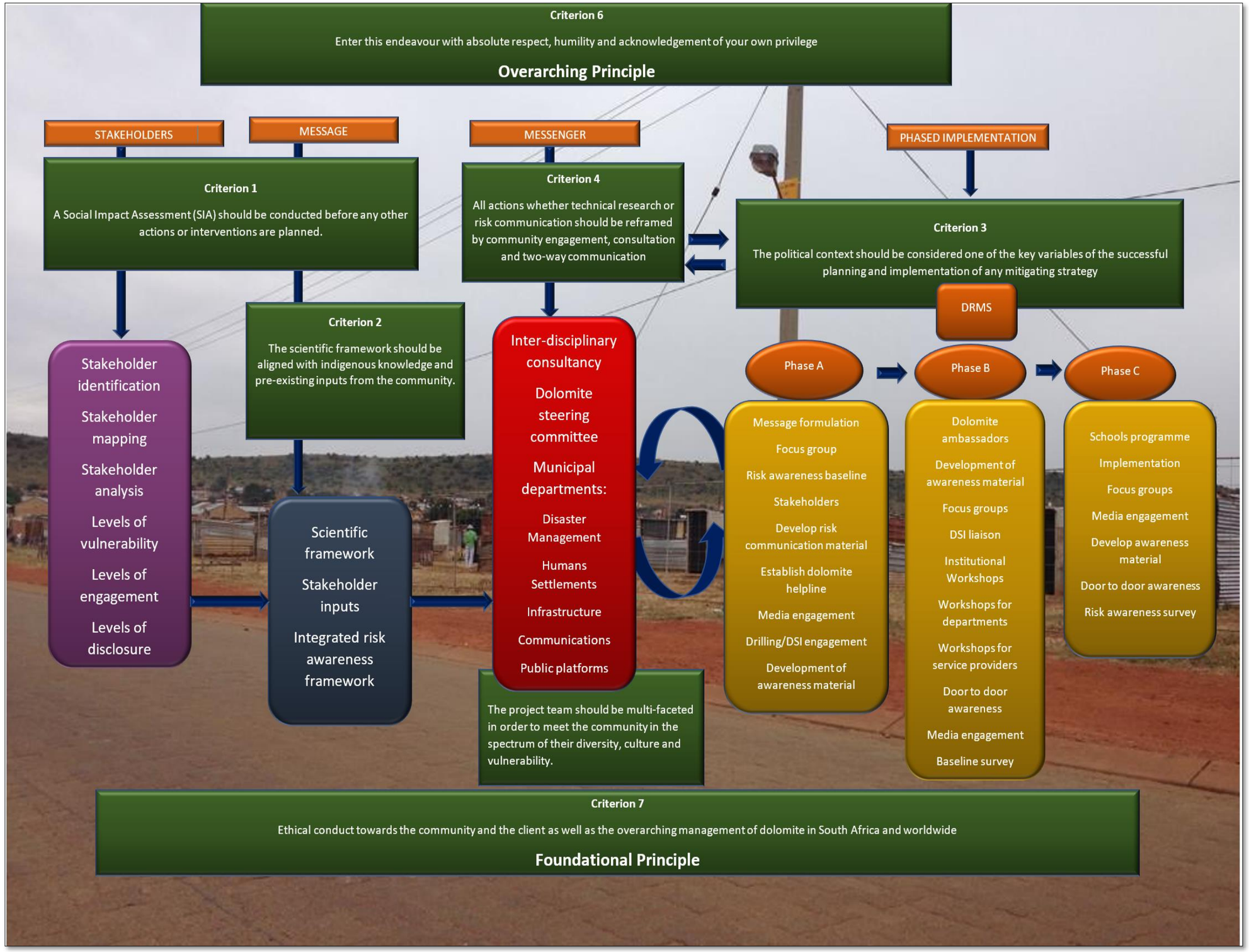


Figure 6-1: Mitigation of anthropogenic risk factors in low-cost residential developments on dolomite integrated framework

6.5 Limitations of the study

The early termination of the DRMS implementation prevented me from having additional focus groups and from measuring the efficacy of the DRCS as a whole when compared to the baseline study conducted at the beginning of the DSI. This additional information would have provided more robust data set to establish criteria and add interventions.

Information regarding other risk communication interventions and the mitigation of risk in low-cost housing implemented by local municipalities and consultants are not available for research purposes.

6.6 Recommendations

The following recommendations are put forward in light of the research outcomes. The outcomes have been expressed as criteria for the implementation of risk communication strategies to mitigate anthropogenic factors in low-cost developments on dolomitic ground.

- The primary recommendation is that the RCS be customised by using the criteria set out in section 6.2.
- Geo-environmental consultancies should not conduct any DSI without community consultation and dissemination of research outcomes in the form of risk communication actions to facilitate mitigation of anthropogenic factors.
- In low-income developments and settlements, the legitimacy of each other's participation as stakeholders should be protected. It is collaboration to reduce risk and not just a linear communication.
- The influence of politics in the successful implementation of DRAP objectives has been described in this study. One must agree with Newcombe (2003:846) that in the mitigation of this additional risk, ethical consideration should be given to what role consultants should play in political activities that affect projects. High levels of risk awareness among politicians and government as well as affected community will contribute to mitigating the risk politics represent.
- Focus groups should be prioritised in order to gain more specific input from the affected community, and to create a platform for consultation with community leaders such as church leaders, managers of NGOs and informal leaders pertaining to the mitigation of influences such as politics in general and narratives that evolved over time. The group should be monitored and varied as to moderate for political influence and fear to speak out.

- In many cases, the primary need for affected stakeholders is to have a place at the table to voice their concerns and be heard. Alternatively, some stakeholders want be involved and play an active and constructive role (Fischhoff, 1995:142). Both needs should be addressed by the DRAP.
- Dolomite risk awareness material should be included in the induction of newly elected ward councillors and ward committee members. SALGA (South African Local Government Association) should be considered a major stakeholder and role player in this regard. SALGA is responsible for the training and preparation of all ward councillors and ward committees in municipalities
- An interdisciplinary as opposed to a multi-disciplinary approach should be implemented. A multi-disciplinary approach requires that technical and social scientists work alongside each other, while an interdisciplinary approach challenges the scientists to function as a team (Bews, 2013:12). In order to align technical research actions with risk awareness actions the scientists should plan every action as a team, where recommendations can be made from the perspective of social scientists regarding technical interventions within the affected community
- One of the recommendations of this study agrees with Cone *et al.* (2013:347). Local authorities and DRMS consultants should not aim to be trusted brokers of risk communication but above all trusted brokers of risk communication dialogue. In connecting stakeholders with the municipality and with each other by means of risk awareness actions such as workshops, an atmosphere of trust and transparency as well as shared responsibility for the dolomite risk can be established

6.7 Contribution of this study and recommendations for further study

6.7.1 Contribution

As illustrated in section 2-1of the thesis gaps have been shown to exist in theory and case studies which examine the mitigation of anthropogenic risk in low-cost development on dolomite.

With this study the only existing example of a total DRMS formulation and implementation including risk awareness interventions have been captured and theorised. The existing guidelines were not adequate to address the complex nature of low-cost housing coinciding with dolomite. The criteria generated through this study will enrich the application of the guidelines compiled in the first phase of the study by Muller (2017).

6.7.2 Further study

The following topics need further study to assist in the mitigation of anthropogenic factors of low-

cost housing on dolomitic areas.

- The prevalence of indigenous knowledge related to environmental issues in different generations towards sustainable mitigation.
- Awareness of anthropogenic risk across low-cost housing settlements on dolomite across local municipalities.
- The influence of housing politics in low-cost housing areas, on dolomite risk perceptions.

6.8 Concluding remarks

The ethic of sustainable development includes the concept that we have a moral obligation to not only this community living in Ikageng or elsewhere on hazardous dolomite, but future generations. We must consider their needs and the environment their children will have to inhabit. All human beings have the same moral worth and therefore the same basic human rights (Stenmark, 2017:3). While acknowledging the role of science in defining the hazard that leads to an assessment of risk, the social and normative dimensions should be considered in the formulation of environmental risk policies and decisions (Stenmark, 2017:21).

A technical question inquiring whether the risk posed by anthropogenic factors in low-income housing developments on dolomitic ground can be mitigated through enhanced risk communication will have an immediate technical answer. In this case, the facts were and are not enough to mitigate the risk. Not even a carefully designed framework for the mitigation of the anthropogenic risk by means of risk communication proved adequate for the task. It is a context in which the communication of the science is critical in addressing the risk for the vulnerable but valuable community and coming generations.

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ANNEXURE A: DECLARATION OF LANGUAGE EDITING

cumlaude
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DECLARATION OF POST-EXAMINATION LANGUAGE EDITING

I, Christina Maria Etrecia Terblanche, hereby declare that I edited the thesis titled:

Mitigation of anthropogenic risk factors associated with low-cost residential development on dolomite

for **D Muller** for the purpose of submission as a postgraduate research study. Suggestions were indicated in track changes and application was left to the author.

Regards,



CME Terblanche

Cum Laude Language Practitioners (CC)

South African Translators Institute accr nr: 1001066

Full member of the Professional Editors Guild

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