

**A spatial multi-risk hazard assessment and
vulnerability study of Madibeng [Northwest Province]**

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INDEX

LIST OF FIGURES	V
LIST OF TABLES	VII
ABSTRACT	VIII
Chapter 1: INTRODUCTION.....	1-1
1.1 PROBLEM DESCRIPTION.....	1-4
1.2 PURPOSE OF THE STUDY.....	1-5
1.3 METHODOLOGY.....	1-6
1.4 STUDY AREA	1-7
Chapter 2: HAZARDS, RISK AND VULNERABILITY.....	2-10
2.1 HAZARDS.....	2-10
2.1.1 Types of hazards.....	2-10
2.1.2 Hazard Assessment	2-12
2.2 RISK.....	2-12
2.2.1 Sources of Risk.....	2-13
2.2.2 Ordinary versus Catastrophic Risks	2-14
2.2.3 Risk Assessment.....	2-14
2.3 VULNERABILITY	2-15
2.3.1 Exacerbating Circumstances	2-16
2.3.2 Risk Perception	2-16
2.3.3 Risk Management.....	2-18
2.3.4 Risk Communication.....	2-19
2.4 GEOGRAPHY IN HAZARD, RISK AND VULNERABILITY ASSESSMENTS	2-20
2.5 GIS IN HAZARD, RISK AND VULNERABILITY ASSESSMENTS	2-20
Chapter 3: MADIBENG HAZARD IDENTIFICATION.....	3-23
3.1 APPROACH.....	3-23
3.2 IDENTIFIED HAZARDS IN MADIBENG	3-24
Chapter 4: NATURAL HAZARDS.....	4-30
4.1 FLOODS.....	4-30
4.1.1 Hazard Identification	4-32
4.1.2 Risk and Vulnerability Assessment	4-33
4.1.3 Conclusions and Recommendations.....	4-42

4.2	VELD FIRE.....	4-44
4.2.1	Hazard Identification	4-46
4.2.2	Risk Assessment.....	4-49
4.2.3	Vulnerability Assessment.....	4-55
4.2.4	Conclusions and Recommendations.....	4-56
4.3	DROUGHT	4-59
4.3.1	Hazard Identification	4-61
4.3.2	Risk Assessment.....	4-62
4.3.3	Vulnerability Assessment.....	4-70
4.3.4	Conclusion and Recommendations.	4-72
4.4	GEOLOGICAL HAZARDS	4-74
Chapter 5:	HUMAN INDUCED HAZARDS	5-77
5.1	POVERTY AND ENVIRONMENTAL DEGRADATION.....	5-77
5.1.1	Causes of Poverty	5-79
5.1.2	Effects of Poverty.....	5-91
5.1.3	Risk Assessment.....	5-95
5.1.4	Vulnerability Assessment.....	5-106
5.1.5	Summary	5-108
5.2	HAZARDOUS MATERIALS	5-110
5.2.1	Hazard Identification	5-111
5.2.2	Hazmat Risk and Vulnerability Assessment	5-118
5.2.3	Summary	5-130
Chapter 6:	CONCLUSIONS AND RECOMMENDATIONS.....	6-131
6.1	GIS FOR DISASTER MANAGEMENT IN MADIBENG	6-132
6.1.1	Data.....	6-132
6.1.2	Processes	6-133
6.1.3	Software.....	6-133
6.1.4	Hardware.....	6-135
6.1.5	People	6-135
6.2	RECOMMENDATIONS.....	6-135
6.2.1	Floods:	6-136
6.2.2	Fire:	6-136
6.2.3	Drought:	6-137
6.2.4	Geological Hazards.....	6-138

6.2.5	Poverty and Environmental Degradation	6-138
6.2.6	Hazardous Materials	6-139
6.3	SUMMARY	6-140
	Bibliography	141
	Appendix A	149

LIST OF FIGURES

Figure 1-1: Deaths from disasters from 1900 to 1990 (Source: Blaikie, 1994).	1-3
Figure 1-2: Madibeng Local Municipality	1-9
Figure 4-1: Major and Minor watercourses in Madibeng	4-32
Figure 4-2: Urban flood hazard scenario	4-36
Figure 4-3: Rural flood hazard scenario.....	4-37
Figure 4-4: Hartbeespoort dam failure hazard scenario.	4-39
Figure 4-5: Vaalkop and Rooikoppies dam failure hazard scenario	4-40
Figure 4-6: Klipvoor dam failure hazard scenario.....	4-41
Figure 4-7: Flood hazard assessment (Booyesen, 2001).....	4-43
Figure 4-8: Average rainfall in Madibeng (mm per annum).	4-47
Figure 4-9: Madibeng fuel categories.	4-52
Figure 4-10: Fire hazard map for Madibeng	4-54
Figure 4-11: Rainfall classification for Madibeng District, 2002.....	4-64
Figure 4-12: Interpolated map of soil depths for the Madibeng area.....	4-65
Figure 4-13: Percentage of clay content in the upper soil layers in the Madibeng area.	4-66
Figure 4-14: Soil potential for Madibeng Municipality	4-67
Figure 4-15: Drought risk map for Madibeng District based on rainfall and soil depth.....	4-69
Figure 4-16: Drought risk and population density per ward in Madibeng.	4-70
Figure 4-17: High drought vulnerability	4-71
Figure 4-18: Major dam catchment areas.....	4-73
Figure 4-19: Madibeng dolomite geology	4-76
Figure 5-1: Madibeng population density per ward.	5-81
Figure 5-2: Population 5-19 year olds per ward and spatial distribution of schools in Madibeng	5-84
Figure 5-3: Madibeng employment rate and employment opportunities.	5-86
Figure 5-4: Poor households and environmental degradation.	5-88
Figure 5-5: Percentage male population per ward.....	5-90
Figure 5-6: Number of households per ward in Madibeng living in poverty.....	5-96
Figure 5-7: Madibeng water sources per ward.....	5-99
Figure 5-8: Madibeng sanitation facilities per ward.....	5-100
Figure 5-9: Madibeng road and rail infrastructure.....	5-103
Figure 5-10: Telephone ownership per ward in Madibeng.....	5-105
Figure 5-11: Brits hazardous materials facilities.....	5-113

Figure 5-12: Madibeng mines and slimes dams.	5-115
Figure 5-13: Necsa	5-116
Figure 5-14: Hazmat transportation routes.	5-117
Figure 5-15: Vulnerable locations to hazmat incidents	5-121
Figure 5-16: Brits industrial area hazmat vulnerability	5-122
Figure 5-17: Mine pollution risk	5-123
Figure 5-18: Necsa risk area.....	5-124
Figure 5-19: Hazardous material transportation: roads	5-127
Figure 5-20: Hazardous material transportation: railway	5-128
Figure 5-21: Brits hazmat routes.....	5-129

LIST OF TABLES

Table 2-1: Classification of hazards in a gradual scale from purely natural to purely human induced (Skidmore, 2002).....	2-11
Table 2-2: Madibeng hazard classification.....	2-11
Table 3-1: Identified hazards in Madibeng.....	3-24
Table 4-1: Settlements at risk of flooding.....	4-34
Table 4-2: Vegetative fuel classification (Van Wilgen, 1997).....	4-44
Table 4-3: Categories of different land covers (fuel loads) and the relief of Madibeng.....	4-51
Table 4-4: Communities at risk of veld fire.....	4-55
Table 4-5: Classification criteria of the drought risk map for Madibeng District	4-68
Table 5-1: Communities at risk of hazmat transportation by road.....	5-125
Table 5-2: Communities at risk of hazmat transportation by railway.	5-126

Abstract

A new act on Disaster Management has been introduced in South Africa that will shift the focus of Disaster Management to a pro-active approach. The new Disaster Management Act, Act number 57 of 2002, states that all Municipalities should provide for: “An integrated and co-ordinated disaster management policy that focuses on preventing or reducing the risk of disasters, mitigating the severity of disasters, emergency preparedness, rapid and effective response to disasters and post disaster recovery”.

Because of this it is important to identify areas that are at risk of any disaster and to introduce mitigating measures to ensure that any foreseeable impacts on the community are limited as much as possible. It is thus important that a disaster risk assessment must be performed for every Municipality that can be used in the planning process.

A great deal of information needs to be gathered and analysed in the risk and vulnerability assessment process. Geographic Information Systems (GIS) provides the ideal platform from which to analyse large quantities of environmental, demographic, cadastral and infrastructural data and represent it spatially and in a format that is easily understandable to everyone.

GIS has proven to be a very important tool in disaster management, from identifying hazards and vulnerable communities, to providing information during disaster events and the recovery process afterwards. It is also a very effective method of gathering and storing data from different fields and applications to be used for planning mitigating measures, setting up standard operating procedures for disaster events and coordination and planning in the event of a disaster.

The purpose of this study was to gather all available information on identified hazards in the Madibeng Municipality and to use this information to perform a risk and vulnerability assessment of the Madibeng Local Municipality with the aid of GIS.

The information provided in this study was intended to assist in building a disaster resistant community by sharing geographic knowledge about local hazards. This study

provides information to the Municipality of Madibeng on hazards and people at risk and vulnerable to different hazards.

Recommendations were then made to the Madibeng Municipality on the application of GIS in hazard and vulnerability assessments, that should provide the Municipality with a cost effective and scientific method of addressing Disaster Management related functions.

Chapter 1: INTRODUCTION

The developing world is a high hazard zone: more than 95 percent of all deaths caused by disasters occur in developing countries; and losses due to natural disasters are 20 times greater (as a percentage of GDP) in developing countries than in industrial countries, according to the World Health Organisation.

The possible explanation for this unequal distribution of disasters could be the result of the three basic needs of man, namely, food, shelter and safety. The best places for man to settle are where these three needs can most easily be satisfied. Locations where all these needs of man are met are very limited (Zschau and Küppers, 2003).

As the world's human population has grown over the years these ideal locations have become very densely populated, eventually forcing people to move from these sites to areas that are less suitable for human habitation. Since the 1960's the world's population doubled from 3 billion to an estimated 6 billion in 2000 (Skidmore, 2002).

When people move into areas that are less suitable for habitation, they will be taking a calculated risk, because the benefits of settling in the specific location will outweigh the drawbacks. Areas that are prone to flooding, for example, are often some of the most popular locations for human settlement, because of the advantages of food production, even though there will always be the danger of flooding (Blaikie, 1994).

Man therefore puts himself at risk by knowingly living in an environment that is not always entirely safe. Sometimes he puts himself at risk by not being aware of a hazard in his environment. Dormant volcanoes are a good example of areas that might seem to be a good place to settle, especially as the slopes of these mountains are very often quite fertile land and ideal for food production. When this mountain then erupts, the community around it is taken by surprise and the consequences are usually much worse than in cases where a hazard has been identified and disasters are expected to occur from time to time (Zebrowski, 1997).

In modern times people have come to know their environment a lot better and can take mitigating measures to minimize the impact of hazards. However, as populations grow, more people move into hazardous areas and today many more people are at risk of disaster than was the case in the past. It is estimated that around 500 million people today are at risk of volcanic eruptions, while the world's total population only reached 500 million in about the 16th century (Amdahl, 2001).

Today people often do not have a choice but to live in hazardous areas because of economic, environmental and demographic reasons. Modern man is often forced to live in a particular area by economic factors, such as the availability of work. Thousands of people flock to cities where they hope to find work and make a living. (Blaike, 1994)

The locations of these cities are very often not ideal and the result is a high concentration of people in a hazardous environment. Even after a disaster has struck it is often not possible for survivors to relocate, because their livelihood is restricted to the hazardous area; for example in mining areas where the location of the mines, and therefore work opportunities, are determined by the locations of mineable minerals (Zschau and Küppers, 2003).

The result is that at present more people are living in hazardous areas and a much higher numbers of people are threatened by disaster. The impacts of disasters are also much bigger than they would have been in the past, because the total number of people exposed to hazards is much higher than was the case in the past. The frequencies of destructive events related to atmospheric extremes are also on the increase. During the last decade, a total of 3 750 wind storms and floods were recorded worldwide, accounting for two thirds of all disaster events (Skidmore, 2002).

A single big disaster event today could lead to thousands of casualties and will have a huge impact on the local environment, economy and community. On a global scale natural disasters have a very limited impact on the human population. Today civil strife and famine cause a lot more deaths than any natural disaster. Figure 1-1 indicates the number of deaths from disasters from 1900 to 1990 (Blaike, 1994).

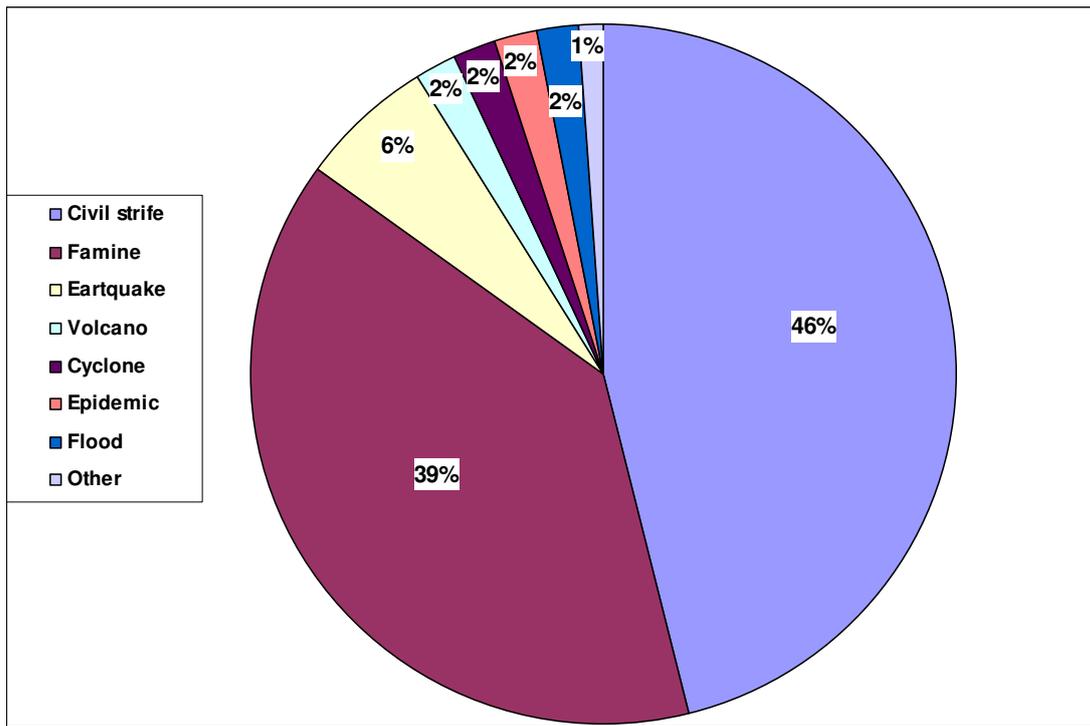


Figure 1-1: Deaths from disasters from 1900 to 1990 (Source: Blaikie, 1994).

On a global scale, the impact of natural disasters is very limited, less than 12% of deaths from disaster events from 1900 to 1990 can be attributed to natural disasters. But because a natural disaster can have a great impact on a local scale, it is important for the purpose of this study (Blaikie, 1994).

The impacts that any disaster has on its environment are always very noticeable and get a lot of attention from the media and scientists studying the causes and effects of such events. In our society there are many more hazards that do not have a huge impact in such a short time frame or over a large geographical area, but are still a threat to the community. Over a longer time span many more people are killed and affected by day to day events such as car accidents and diseases that might be the result of the polluting and degrading of our environment (Miller, 1999).

In the long run these smaller events have a much bigger impact on our society than natural disasters. It is therefore important for disaster management to consider all possible hazards and not only the bigger events, so as to be able to create a safer living environment for the whole community.

1.1 PROBLEM DESCRIPTION

It seems that there is a correlation between the level of development of a country and the loss of lives during a disaster. Economic losses attributable to natural hazards in less developed countries may represent as much as 10% of the country's gross domestic product. In industrialized countries, where pre-warning systems are more sophisticated, it is more feasible to predict the occurrence of certain natural phenomena (Skidmore, 2002).

In the past, disaster management had a reactive function, organizing and managing relief and rescue efforts after a disaster struck. Today it is recognized that a pro-active approach is far more important to limit life and economic losses, although the reactive function is still very important.

Accordingly, in South Africa a new act on Disaster Management has been introduced that will focus on this new approach. The new Disaster Management Act, Act number 57 of 2002, states that all Municipalities should provide for: "An integrated and co-ordinated disaster management policy that focusses on preventing or reducing the risk of disasters, mitigating the severity of disasters, emergency preparedness, rapid and effective response to disasters and post disaster recovery".

Because of this it is important to identify areas that are at risk of any disaster and to introduce mitigating measures to ensure that any foreseeable impacts on the community are limited as much as possible. The identification of such risk areas is very much a spatial problem and therefore Geographers can play a very important role in disaster management (Greene, 2002).

A great deal of information needs to be gathered and analysed in the risk and vulnerability assessment process. Geographic Information Systems (GIS) provides the ideal platform from which to analyse large quantities of environmental, demographic, cadastral and infrastructural data and represent it spatially and in a format that is easily understandable to everyone (Greene, 2002).

The government has a very limited budget to spend on disaster management, therefore it is important to identify areas where people are vulnerable to hazards so that limited resources can be distributed to where they are needed most. Assessing risk and vulnerability is an ongoing process, as people are constantly moving and spatial distribution patterns also change. To provide accurate real-time data is extremely important for disaster management, to ensure that budgets are spent wisely in protecting those who are most at need (Longley *et al.*, 2001).

GIS has become a very important tool in disaster management, from identifying hazards and vulnerable communities, to providing information during disaster events and the recovery process afterwards. It is also a very effective method of gathering and storing data from different fields and applications in a central database from which it is available to all role players, for planning mitigating measures, setting up standard operating procedures for disaster events and coordination and planning in the event of a disaster. The availability of accurate and understandable information will also assist the community at risk to protect themselves from any hazard that threatens them or their livelihood (FEMA, 1997).

1.2 PURPOSE OF THE STUDY

The purpose of this study is to gather all available information on identified hazards in the Madibeng Municipality and to use this information to perform a risk and vulnerability assessment of the Madibeng Local Municipality with the aid of GIS.

The information provided in this study is intended to assist in building a disaster resistant community by sharing geographic knowledge about local hazards. This study will provide information to the Municipality of Madibeng on hazards and people at risk and vulnerable to different hazards. It would also test the effectiveness of applying GIS to disaster management in a smaller municipal area in South Africa.

If successful, the hazard and vulnerability analysis will provide the Madibeng Municipality with the next logical step for prioritizing hazard mitigation initiatives. From this data it will be possible for decision-makers to apply resources to where they are most needed,

whether for further research on hazards or mitigating actions in vulnerable areas. It also provides the community with information that will empower them to protect themselves from hazards in their environment.

The main aims or objectives of this study are the following:

- Identify all possible hazards that pose a threat to the community of Madibeng.
- Create maps of identified hazards.
- Using GIS, assess the disaster risk associated with each hazard.
- With the aid of GIS, identify communities that are vulnerable to these hazards.
- Create maps of vulnerable communities.
- Recommendations on the application of GIS in Disaster Management in Madibeng

1.3 METHODOLOGY

To assess the risk of different hazards and the vulnerability of people to these hazards, a wide range of physical, spatial and demographic data of Madibeng Municipality is needed. Because of financial and time restraints only readily available data was gathered and used in the study.

On the 27th of May 2002, a meeting was held with representatives of Disaster Management and the various municipal departments of Madibeng, during which questionnaires were handed out to identify all possible hazards and begin the process of gathering information on all the identified hazards. Later meetings were also held with all the departments to discuss the questionnaires and gather available information.

Where possible, GIS maps were created with the available information of areas at risk from all the identified hazards. These risk maps will be overlaid with maps of the communities and infrastructure to assess the vulnerability of communities in the municipality to the different hazards.

From the different risk and vulnerability maps it should then be possible to identify areas where people are currently at risk and where hazard mitigation measures are urgently

needed. Using this information it should be possible for Madibeng Disaster Management to allocate resources to the priority areas.

1.4 STUDY AREA

Madibeng is situated in the eastern part of the North West Province with Gauteng on its southern border and the Limpopo Province on its northern border, as is indicated in Figure 1-2.

- Climate

The North West Province is mostly a dry region, especially in the west, but the eastern area, where Madibeng is situated, generally has a subtropical, semi-arid climate making it suitable for subtropical farming.

It is a warm province, and it can be very hot in summer, although frost can occur in the south and east in winter. Summer rainfall in Madibeng varies from around 500mm in the north to over 700 mm in the south and southeast, which areas are very suitable for a variety of agricultural activities (State of the Environment Report, 2002).

- Economy

The area around Brits comprises fertile mixed-crop farming lands, where tobacco, citrus, paprika, wheat, peppers, cotton and sunflower are produced. There are a number of game farms and conservation areas in Madibeng, which gives the Municipality potential for eco-tourism activities. Mining also plays an important role in the economy of the Municipality as the area around Brits and Rustenburg is the largest single platinum production area in the World. Marble is also mined in Madibeng and mostly destined for the export market (Routes Travel Info Portal, 2004).

Industry in the area is centred around Brits and concentrates mostly on manufacturing and construction, while commercial activities are characterised by small, medium and micro-enterprises.

- Demography

Population data available is still from the 2001 census and, according to this data, there was a population of 337084 people living in Madibeng. The trends in urbanization, rural poverty and the boom in the platinum industry would probably have caused a significant increase in the total population in Madibeng since 2001.

Although the Municipality provides ample job opportunities, a large percentage of the population is still living in extreme poverty, especially in the Northern region (Census, 2001).

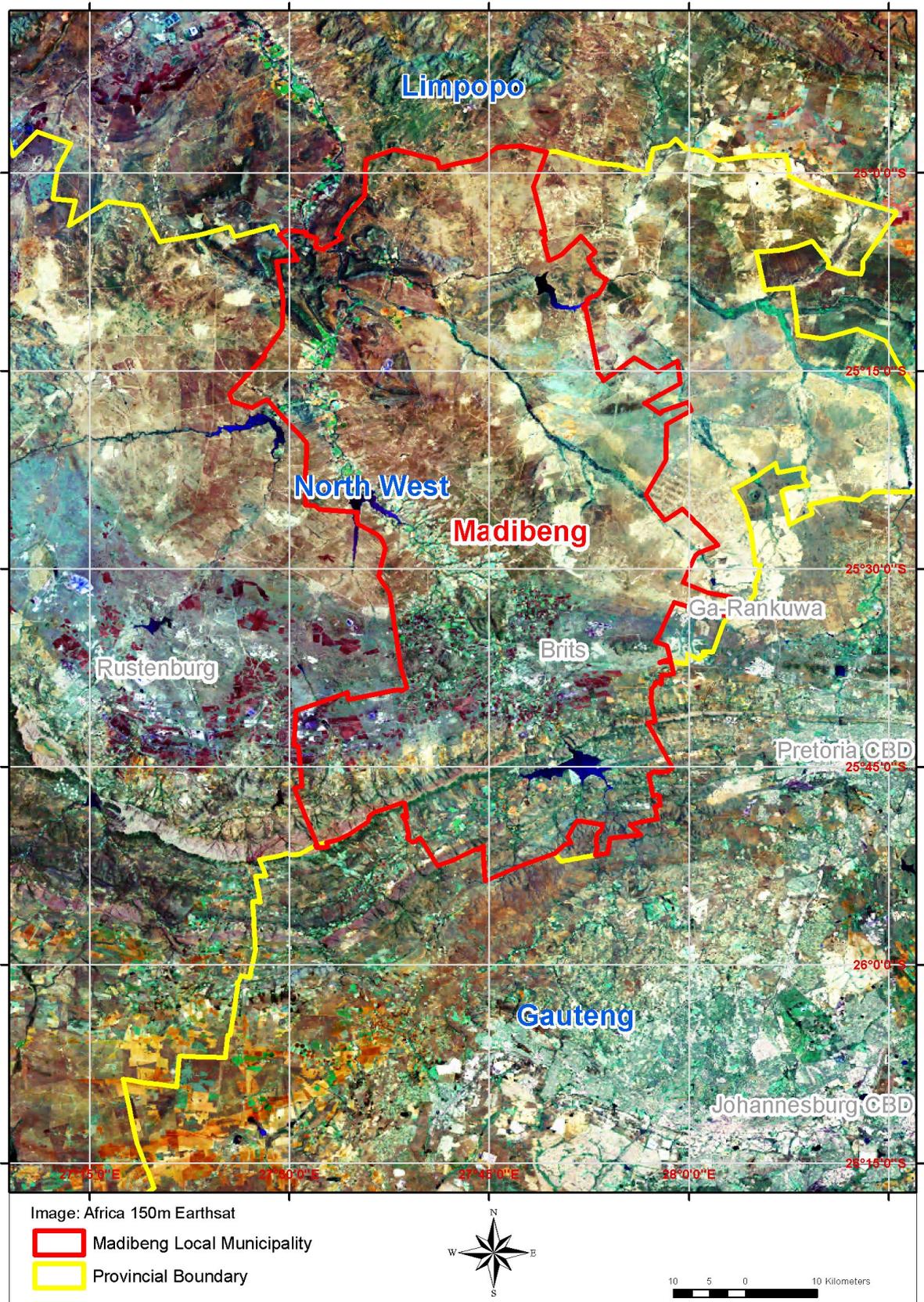


Figure 1-2: Madibeng Local Municipality

Chapter 2: HAZARDS, RISK AND VULNERABILITY

Chapter 2 is intended to give the reader a background on the nature and types of hazards, risks and vulnerability and also the principles of assessing these three concepts. Furthermore this chapter attempts to illustrate how the concepts of hazards, risk and vulnerability are perceived throughout this study.

2.1 HAZARDS

A hazard is a physical situation with a potential for human injury, damage to property, damage to the environment or some combination of these. It is important to distinguish between the terms 'disaster' and 'hazard'. A potential damaging phenomena (hazard) only has the potential of becoming a disaster event when it occurs in populated areas where it can cause loss of life or major economic losses (Allen, 1992).

A disaster is seen as a serious disruption of the functioning of a community or society, causing widespread human, material, economic or material losses which exceed the ability of the affected community to cope, using its own resources. Disasters can be either natural (floods), or caused by humans (nuclear accident) and can furthermore be classified as slow-onset disasters (such as a drought) or sudden disasters (earthquake) (RAVA, 2002).

2.1.1 Types of hazards.

Hazards can be classified in a number of different ways. The first distinction is between natural hazards and those caused by humans. This method of classifying hazards can vary on a gradual scale from purely natural hazards to those of purely human origin. This method of classification illustrates the effect humans have on their environment and vice versa (see Table 2-1). For example, a landslide can be purely natural, due to heavy rainfall or earthquake, but it may also be human induced as a result of the removal of vegetation (Skidmore, 2002).

Table 2-1: Classification of hazards in a gradual scale from purely natural to purely human induced (Skidmore, 2002).

Natural	Some human influence	Mixed Natural / Human influence	Some natural influence	Human
Earthquake	Flood	Landslides	Crop disease	Civil Strife
Tsunami	Dust storm	Erosion	Insect infestation	Land mines
Volcanic eruption	Drought	Desertification	Forest fire	Air-, land-, sea- and traffic accidents
Snow storms		Coal fires	Acid rain	Oil spills
Lightning		Global warming	Ozone depletion	Pollution
Windstorm		Rising sea levels		
Thunderstorm		Coastal erosion		
Tornado				
Cyclone				
Hurricane				
Asteroid impacts				

For the purpose of keeping the questionnaire used in this study as simple as possible, hazards were classified as either natural or human induced. Natural hazards were then further divided into biological and physical hazards, and human-induced hazards into chemical and cultural hazards, as can be seen in Table 2-2.

Table 2-2: Madibeng hazard classification

Natural Hazards	-Physical Hazards	Floods, fire, hail, snow and wind storms
	-Biological Hazards	Diseases (human and animal) Dangerous plants and animals
Human induced Hazards	-Chemical Hazards	Pollution of air, water, soil and food
	-Cultural Hazards	War, poverty, accidents and lifestyle choices including drinking and smoking

2.1.2 Hazard Assessment

There are three methods of identifying natural and human induced hazards:

- The first is by reviewing past occurrences of hazards and their impacts through historical records.
- The second is to develop hazard scenarios with the help of scientific models that can predict a specific hazard scenario (Miller, 1999).
- The auditing of historical records can provide insights into past experiences and impacts associated with hazardous events that occurred in the past. The identification of areas where there are high road accident rates is a good example of using historical data to identify high hazard areas for road users.

Hazard scenario mapping involves the use of layers of scientific data in a GIS system and the use of scientific models to identify the location and magnitude of possible hazards. The assessment of fire prone areas is a good example, in that models of fuel loads and fire intensities of different vegetation types can be combined with spatial land cover information to create a fire hazard map (Bankoff et al., 2004).

These are the two most scientific methods of hazard assessment, but because the perception of the local community regarding hazards in their environment can differ from the scientific interpretations, it is also important to get some input from the local community in the hazard identification process (RAVA 2002).

2.2 RISK

For the purpose of this study, risk is defined as the possibility of suffering harm from a hazard that can cause injury, disease, economic loss or environmental damage. Risk can be expressed in terms of:

- A probability: a mathematical statement about how likely it is that some event or effect will occur, or
- Frequency: the expected number of events occurring in a unit time (Allen, 1992).

The word 'risk' is one of the most notable examples of words with multiple and disparate meanings that may not be commonly acknowledged. Risk may have a technical meaning, referring to a chance or probability (risk from exposure), a consequence or impact (the risk from smoking), or a perilous situation (a nuclear power plant creates a risk) (Gerrard *et al.*, 2001).

Usage of the word 'risk' in the context of this study incorporates two ideas:

- That the situation being discussed has the potential for undesirable consequences and there is some uncertainty associated with the circumstances.
- There is uncertainty whether a hazardous event will occur, when or where it will occur, who or what will be affected and the magnitude of the consequences.

Risk in this sense includes both the probability and the character of the undesirable event. Risk then as a simple definition refers to uncertain events that can damage the well being of an individual or group (Scoones, 1996).

2.2.1 Sources of Risk

Human actions very often amplify the consequences of a disaster event; for example houses built in a floodplain are more likely to be damaged than houses built on higher ground (Gerrard *et al.*, 2001).

Three primary sources of risk are generated by human action:

- Lifestyle choices are voluntary choices we make ourselves that put us at risk. For example, excess drinking and smoking can be a health risk, and exceeding speed limits when driving increases the risk of being in a traffic accident.
- Contractual arrangements normally have some or other economic influence, especially regarding people who work in hazardous circumstances. Police officers, for example, knowingly put themselves at risk through their career choice, but expect some offset. Another example would be a person purchasing a house near a busy airport. The person puts himself at risk of noise pollution and the danger of an aircraft accident in exchange for lower real estate values.

- Externalities from choices by others mean that actions by one party create risks or costs for others. Water and air pollution by firms and an accident due to a drunk driver are good examples of externally imposed risks (Gerrard *et al.*, 2001).

2.2.2 Ordinary versus Catastrophic Risks

For the purposes of disaster management, a reasonable objective would be to target risk regulation efforts to maximize the expected numbers of lives saved for the resources spent. Such an approach would treat two situations equally:

- Where one person faces a risk of 1/1 000
- The other where 100 people together face a risk of 1/100 000

In each case the number of expected casualties would be the same over a given period of time. But the death of 100 people in an aircraft accident or flood event would typically receive much more attention than the separate deaths of 100 individuals in non-related events such as automobile accidents. Society is especially concerned with large-scale catastrophes (Gerrard *et al.*, 2001).

Extensive media coverage also leads people to overestimate certain risks and give undue importance to catastrophic events. For example, the thousands of lives lost to the HIV/Aids epidemic should merit the same preventive efforts as those that will be lost due to a highly visible catastrophe such as a major aircraft accident (Gerrard *et al.*, 2001).

2.2.3 Risk Assessment

Risk assessment involves determining the types of hazards involved, estimating the probability that each hazard will occur, estimating how many people are likely to be exposed to it and how many may suffer serious harm. The risk assessment process involves using data, hypotheses and models to estimate the probability of harm to human health, to society, or to the environment, that may result from exposure to specific hazards (Miller, 1999).

Risk assessment emphasizes the estimation and quantification of risk in order to determine acceptable levels of risk and safety; in other words to balance the risk of a

technology or activity against its social benefits in order to determine its overall social acceptability (Cutter, 1993).

There is considerable disagreement over the use of risk assessment. Most of these conflicts centre on scientific issues of measurement, inference and use of quantitative data. In theory risk assessments are objective attempts to numerically define the extent of human exposure to all the hazards they face. Unfortunately we know that science is not always objective, as scientists tend to disagree on the interpretations of the quantitative evidence, depending on their own personal points of view (Lofstedt and Frewer, 1998).

2.3 VULNERABILITY

Because the risk that people face is a complex combination of vulnerability and hazard it is most important that the term 'vulnerability' is well understood. Vulnerability is a central theme in hazard research, yet there is very little consensus on its meaning or exactly how to assess it. Questions of geographical scale and social referent (individual, household, community, society) add to the confusion. Are we talking about vulnerable people, places or societies and at what scale: local, national, regional or global (World Bank, 2000).

Most of the vulnerability research to date focuses on natural hazards or global change and either examines vulnerable places based on biophysical or environmental conditions, or vulnerable people governed by political and economic conditions. Vulnerability must be viewed as an interactive and dynamic process that links environmental risks and society (Cutter, 1993).

In the dimensions of income and health, vulnerability is the risk that an individual or household will experience an episode of income or health loss over time. But vulnerability also means the probability of being exposed to a number of other risks (violence, crime, natural disasters, etc.) (United Nations Development Programme, 2004).

In the context of this study, vulnerability can be described as set of conditions and processes resulting from physical, social, economic and environmental factors, which may increase the susceptibility of a community or location to the impacts of hazards.

It is also important to remember that vulnerability is dynamic, not static, as the vulnerability of communities change due to improvements or degradation of social, environmental and economic conditions, as well as interventions specifically aimed at reducing vulnerability, such as disaster mitigating actions (Zschau and Küppers, 2003).

2.3.1 Exacerbating Circumstances

In Ecuador, El Nino may have increased the incidence of poverty in affected areas by more than 10 percentage points. During the 1984 drought in Burkina Faso, the income of the poorest third of the rural population fell by 50 per cent in the Sahelian zone (United Nations Development Programme, 2004).

Poor people and poor communities are frequently the primary victims of natural disasters, in part because they are priced out of the more disaster proof areas and live in crowded makeshift houses. The incidence of disasters tends to be higher in poor communities, which are more likely to be in areas vulnerable to hazards such as flooding. In addition, there is evidence that the low quality of infrastructure in poor communities increases their vulnerability (May, 1998).

While natural disasters hurt everyone affected by them, poor families are hit particularly hard because injury, disability and loss of life directly affect their main asset, their labour. Disasters also destroy a poor household's natural, physical and social assets, and disrupt social assistance programs (Zschau and Küppers, 2003).

2.3.2 Risk Perception

Individuals, scientists, farmers, public servants, aid workers and politicians all view the hazards of the everyday world from different perspectives. The way that risks are perceived and responded to is based on educational background, gender, age, historical and personal experience, attitudes and behaviours derived from peers, friends and family (Scoones, 1996). For example, a study done in the south of Zimbabwe by Scoones 1996, found that the most common reason given for the occurrence of drought by farmers in the area is moral decline. Lack of respect and changes in the moral order were seen to

result in retribution from God or the Ancestors. On the other hand scientists blamed the El Nino effect for a rise in average temperatures that led to a decline in precipitation in the area.

Most people assess the risks they face in everyday life very poorly. Most individuals do not care much about the voluntary risks they face in everyday life. For example, the risk of dying in a motorcycle accident (1 in 50 participating) or driving (1 in 2500 without a seatbelt and 1 in 5000 wearing a seatbelt) is largely ignored, yet a lot of us are terrified of a shark attack (1 in 300 million) or dying in a commercial aeroplane crash (1 in 4.6 million) (Miller, 1999).

Our perceptions of risk and our responses to perceived risks often have little to do with what the risk experts have calculated, but we generally use the following criteria to assess our own risk.

General features of public risk perception are:

- Concentrated and obvious risks are regarded as worse than the risk from small-scale events, even when large numbers of deaths occurs. For example, a bus accident in which 30 people are killed will receive much more publicity than 30 separate accident events in which the total death toll could be more than 30, but fewer than 2 people are killed per accident.
- Involuntary risks are regarded as worse than voluntary risks.
- Unfamiliar or new risks are regarded as worse than risks from familiar, natural or established hazards.
- Risks which are seen as inherently uncontrollable are regarded as worse than risks that can easily be mastered.
- Risks evaluated by groups who are suspected of not being independent or competent enough are regarded as worse than risks evaluated by clearly impartial and competent groups.
- Immediate hazards are regarded as worse than deferred hazards.
- Risks from which there is no immediate benefit are regarded as worse than risks giving such benefit.
- Risks to named and clearly identified people are more important than risks in which no identified individual is under threat.

- Risks to an individual in a small group are less important than risks to an individual in a larger group.
- Risks over which the individual or community has no direct control are regarded as worse than those for which there is such control (Lofstedt and Frewer, 1998).

2.3.3 Risk Management

Once an assessment of the risks in an area is made, decisions must be made as to how to address these risks. Risk management includes the administrative, political and economic actions taken to decide whether and how to reduce a particular risk to a certain level and at what cost (Miller, 1999).

Risk management involves deciding:

- Which of the vast number of risks facing society should be evaluated and managed and in what order or priority with the limited funds available.
- How reliable the risk assessment performed for each risk is.
- How much risk is acceptable.
- The cost of reducing a risk to an acceptable level.
- How much each risk can be reduced using available funds.
- How the risk management plans will be communicated to the public (Miller, 1999).

Once the risk manager has decided what risks have to be reduced and by what margins, the following methods can be implemented to achieve the desired targets.

Methods of reducing an identified risk include the following:

- Avoiding the risk altogether (Closing a factory that produces hazardous materials eliminates the risk of pollution from that facility).
- Regulating or modifying the hazard to reduce the associated risk (Lowering speed limits might reduce the number of fatal road accidents)
- Reducing the vulnerability of exposed persons or property (Providing proper infrastructure reduces a community's vulnerability to disease, as they then have better access to clean drinking water, health facilities and electricity).

- Developing and implementing post event mitigation and recovery procedures (Providing fire-fighting equipment, training volunteer search and rescue teams, e.g. The NSRI)
- Instituting loss reimbursement and loss distribution schemes (Insurance, Drought relief programs, etc.) (Gerrard *et al.*, 2001)

2.3.4 Risk Communication

Risk communication is a process that develops and delivers a message from the experts to the public. This one-way flow of information is designed to enable the public to understand better the risk of a particular hazard. The assumption is that if the public understands the hazard and the method of calculating the risk associated with such a hazard, then they would be more acceptant of any risks involved (Cutter, 1993).

Unfortunately many problems are experienced with risk communication, such as the credibility of either the message or its source, self-serving or selective use of information in the message and contradictory messages from other highly regarded sources. Messages must also be understandable to the general public, without losing too much of their scientific content. Issues of uncertainty should be expressed in terms that are easily understood, rather than numerical or probability terms (Cutter, 1993).

Risks need to be measured against something in order to be meaningful. Depending on the analytical technique used, risk comparisons can produce very different conclusions on the relative magnitude of the risk under investigation.

While messages from the expert are important, it is the general public that should provide the values to assess the scientific facts and their acceptance or rejection. Nuclear facilities are a good example, as according to experts the benefits of a nuclear power plant by far outweigh the risks. However, the general public has a different perception of the risks associated with such a facility and do not necessarily value the benefits in the same way (Barrow, 1997).

2.4 GEOGRAPHY IN HAZARD, RISK AND VULNERABILITY ASSESSMENTS

The relationship between people and their environment is viewed as a series of adjustments in both the human use and natural processes. A change in the natural environment, such as a major flood, would have an immediate effect on the distribution of settlements in that area. On the other hand the building of a dam would alter the natural river system (Coch, 1992).

Hazards are connected with the geophysical processes that initiate them; for example, stress in the earth's crust can cause solid rock to deform until it suddenly fractures and shifts along the fracture, producing a fault. The faulting, or a later abrupt movement on an existing fault, can cause an earthquake. It is the interaction of this extreme event with the human conditions in particular places that produces the hazard and influences responses to it (Miller, 1999).

Risk is synonymous with the distribution of these extreme events or natural features that give rise to them. Much of the early hazard work mapped the locations of these extreme events to delineate risks. These early studies also mapped the human occupancy of these hazard-prone areas and could thereby study the relationship between hazards (natural environment) and risk (human occupancy) (Foster, 1980).

These early hazard identification, assessments and risk assessments were therefore pure Geographic applications. With new advances in Geography, especially in Geographic Information Systems (GIS) and the availability of digital environmental, demographical and economic data, hazard- and risk assessments have become an important Geographical application (Greene, 2002).

2.5 GIS IN HAZARD, RISK AND VULNERABILITY ASSESSMENTS

There are many alternative definitions of Geographic Information Systems (GIS), but a simple definition is that a GIS is a computer based system for the capture, storage, retrieval, analysis and display of spatial data. GIS are differentiated from other spatially

related systems by their analytical capacity, thus making it possible to perform modelling operations on the spatial data.

GIS technology was originally developed as a tool to aid in the organization, storage, analysis and display of spatial data. The ultimate goal, however, was its application in geographical analysis. GIS has since evolved to include environmental models, decision support systems and expert systems in order to make these systems applicable in a wide variety of spatially orientated planning and decision making activities (Skidmore, 2002).

GIS allows a user to:

- Import Geographic data such as maps.
- Manipulate Geographic data and update maps.
- Store and analyse attribute data associated with Geographic data.
- Perform queries and analyses to retrieve data (For example, show all the clinics in Madibeng that are located within the dam failure scenarios).
- Display the results as maps or graphs.

GIS allows users to overlay different sets of data to determine relationships among them. Maps produced with GIS can help explain hazard events, predict the locations of hazard events, predict outcomes, visualize different scenarios and help in planning strategies (Federal Emergency Management Agency, 1997).

GIS is a tool used for improving the efficiency and effectiveness of a project in which geographical knowledge is of prime importance. The information in a GIS consists of two elements: spatial data represented by points, lines and polygons, or grid cells and attribute data or information that describes characteristics of these spatial features. The spatial data are referenced to a geographical spatial coordinate system and are stored either in a vector or raster format (Burrough and Mcdonnell, 1998).

Some communities and regional planning authorities maintain GIS databases for urban planning and utility management purposes. This land use and infrastructure data provide the baseline information for a hazard assessment, as it is possible to map the extent of a hazard and compare it to this data.

It is possible to profile the geographic extent of hazards because they very often occur in predictable locations. Predictions are based on statistical theory and historical records of past events resulting in average probabilities for future events, thus enabling the use of modelling in GIS. Once the possible extent of a hazard is known, it is then possible to identify communities, resources and infrastructure at risk (Zschau and Küppers, 2003).

Knowledge about how the world works is more important than knowledge about how the world looks, because such knowledge can be used to predict. The characteristics of a specific location are unique, whereas processes are very general. For example, the environmental conditions and landscape in Madibeng would differ drastically from those of Perth, Australia. However, in the case of veld fires the same fuel type and quantity would burn similarly in both areas under the same climatic conditions (Longley et al., 2001).

These assessments are in some sense ideals, as no assessment can anticipate every eventuality, nor is such an assessment ever really finished, since hazard conditions are constantly changing. It is also important that the information gathered in such an assessment is communicated in an uncomplicated yet accurate format, easily understandable to experts and non-experts alike (Greene, 2002).

GIS allows us to put the accurate physical Geography of a hazard event on a computer monitor and then to overlay other relevant features, events, conditions or threats on that Geography. Combined with scientific models it enables the scientist to predict the extent and impact of a hazard event on the specific location.

GIS can display the location, size, value and significance of assets. It can also show the kinds of environmental, atmospheric and other conditions that give rise to particular kinds of natural hazards. This enables disaster management-, police-, medical-, fire- and other managerial personnel to make decisions based on data they can see and judge for themselves. This spatial or Geography based method presents necessary information in a way which is far more real and understandable than any other (Greene, 2002).

Chapter 3: MADIBENG HAZARD IDENTIFICATION.

Chapters 1 and 2 gave a background of the importance of disaster management, the definitions and short descriptions of hazards, risk and vulnerability and the value of GIS as a tool in the assessment of hazards, risk and vulnerability.

The process of identifying hazards as described in Chapter 2 was applied in this chapter. As it was foreseen that there would not be data available on all types of hazards, it was also deemed important to establish, firstly, if data was available and secondly the format and quality of available data.

Workshops with local representatives of Madibeng and a questionnaire survey (Appendix A) were used to identify hazards and suitable data to be used in this study.

3.1 APPROACH

Two approaches were followed to identify possible hazards in the Madibeng Local Municipality. The first approach was to discuss Table 2-2 in a workshop with representatives of Madibeng, to identify commonly known hazards and identify the hazards that could occur in the Municipality.

The second was to hand out questionnaires to all Local Government Departments, Emergency Services, Local Police and Commando. This questionnaire included a section for the identification of possible hazards and disasters as well as a section in which the availability and status of data could be indicated.

The respondents used their knowledge of historical events to identify hazards and, where possible, to indicate their locations on a map of Madibeng Municipality. Respondents then indicated whether information on identified hazards is available; in what format the data is; whether spatial data on the hazard are available, and a contact name and details as to where the data could be gathered.

Unfortunately, because of the methodology of the study and the timeframe within which the project had to be completed, only readily available data, mostly in digital format, could be used. This meant that although a great number of hazards were identified, not all could be represented in the study due to a lack of suitable information.

Obtaining complete and up-to-date data about hazards and assets should be an overriding concern in all the stages of any GIS-focused hazard mitigation program. It was of great concern that so little information was readily available and that there was much difficulty experienced in gathering the relevant information from the different parties.

3.2 IDENTIFIED HAZARDS IN MADIBENG

The following table indicates all the hazards that were identified in Madibeng with a short description of the hazard and an indication as to whether the hazard is covered in GIS format in this study.

Table 3-1: Identified hazards in Madibeng.

Hazard	Comment	GIS
Natural/Hydro meteorological/Climate		
Extreme weather conditions (Heavy rain, strong winds, lightning, hail and heat waves)	<p>Madibeng has a relatively warm and dry climate, but episodes of extreme weather conditions have been experienced in the past.</p> <p>Lightning and hail have been identified as hazards in the survey. Hail can cause damage to crops and livestock, while lightning is a hazard especially at the beginning of the rainy season when vegetation has a low moisture content and is therefore vulnerable to ignition.</p>	No

Natural/Hydro meteorological/Hydrological		
Floods	Flooding has occurred in Madibeng Municipality in the recent past and will continue to occur.	Yes
Drought	The whole of South Africa is prone to extended periods of dry weather that could cause serious water shortages.	Yes
Natural/Geological		
Seismic hazards	Although the risk of a major earthquake in Madibeng is considered to be very low, the risk of such an event happening should not be ignored.	No
Rock falls	Rock falls are a hazard on roads in mountainous areas especially after heavy rains.	No
Sink-holes	Sink-holes are a hazard in areas located on dolomite geological structures. Dolomite is known to form underground caverns that could collapse and cause sink-holes. These sink-holes are often the result of the lowering of the water table due to over-exploitation of groundwater resources. Caverns that were previously filled with water may become unstable if they become empty and cause the roof of the caverns to collapse, sometimes exposing a hole on the surface that is then referred to as a sink-hole (Venter, 2004).	Yes
Natural/Biological		
Veld fires	Veld fires are a constant threat throughout the country, especially during dry periods with high temperatures. Relief has a powerful influence on fire behaviour. The movement of air over the terrain tends to direct a fire's course. Aspect also has an influence as solar heating of drier, north-facing slopes produces upslope thermal winds that complicate fire behaviour.	Yes

	<p>The slope of an area has a big influence on the spread of fire. Each 10% increase in slope doubles the rate of spread of a veld fire.</p> <p>The Madibeng Municipality is situated in an area characterized by relatively high temperatures, seasonal dry periods and a relief that can have a major influence on the spread, behaviour and fighting of fires.</p> <p>Fires are also a serious threat to informal settlements, due to a lack of infrastructure, building materials used and the use of fossil fuels as a primary energy source. The locations of informal settlements, composition of structures, existing infrastructure and energy sources used in the area, are all-important information needed to perform a fire risk assessment of informal settlements.</p>	
Epidemics	<p>Areas with a high population density, poor infrastructure, lack of medical facilities and low income levels, are especially at risk of diseases such as TB and Cholera. Poverty creates the ideal environment for diseases to arise and spread</p>	No
Disease	<p>HIV/Aids is a serious threat in Southern Africa.</p> <p>Foot-and-mouth disease has occurred in Madibeng in the past and can be seen as a potential hazard to livestock farming in the area.</p>	No
Plants	<p>The following intrusive plants have been identified in Madibeng: Sickle bush, Lontana, Acacia Mellifera, Water Hyacinth, “Nagblom”, Bugweed, Poplar, Bluegum and Syringa</p> <p>A number of plants that occur in Madibeng are also classified as poisonous and could be hazardous to humans and animals: Poison Leaf, Amaranth, Syringa, Castor-oil bush, Cancer bush and Wild cotton.</p>	No

Environment/Air		
Pollution	<p>South Africa's atmosphere is generally very stable, with frequent surface and elevated inversions, particularly in winter. This means there are periods when there is little or no wind and air pollutants are trapped and so accumulate instead of being blown away.</p> <p>The burning of fossil fuels in industry, for power generation and by less developed communities as a primary energy source, causes pollution problems especially in densely populated areas.</p> <p>The large concentrations of mines in Madibeng have been identified as pollutants of the environment; unfortunately no data could be gathered to map the extent or impact of pollution. Herculite Ferrochrome near Brits has been involved in chrome 6 pollution and it is clear that mines contribute to air pollution in the area.</p>	No
Environment/Vegetation		
Agricultural practices	Over utilisation of natural resources puts extreme pressure on the environment, especially in areas that are prone to fluctuations in rainfall. This could lead to environmental degradation.	Yes
Environment/Water		
Pollution and disappearing wetlands	<p>Water is the most valuable resource in the whole of South Africa. Madibeng has been vulnerable to water shortages in the past and it is therefore very important to protect the rivers, dams and wetlands in the area.</p> <p>The Herculite Ferrochrome plant was responsible for a chrome 6 spill and it is also suspected that other mines, informal settlements and agriculture are responsible for the pollution of rivers in Madibeng.</p>	No
Environment/Soil		
Degradation	Land degradation is a hazard in areas where communities are dependent on their natural environment for a living, especially in densely populated areas such as the former	Yes

	Homelands.	
Human Induced/Environmental		
Exotic plantations	Although plantations are economically of great value, these exotic species also use greater amounts of valuable water than the natural vegetation, putting strain on the natural environment and eventually on communities depending on natural water supply.	No
Human Induced/Technological/Installations		
Power plants, fuel depots, large industry, gas and electricity, dams , bridges, mines and sewerage works	<p>Society has become increasingly aware of the impacts industry can have on the environment. It is important to identify installations and facilities that generate or store potentially harmful substances, in order to identify the specific hazard associated with each location. Information on the types and quantities of the different substances stored, generated and produced, is important in determining the risk associated with each installation/facility.</p> <p>Other structures that could be seen as hazardous are dams and bridges. Dam failure scenarios should be generated for all large dams that pose a risk to people and infrastructure. Bridges that are damaged or poorly maintained could also be a serious hazard.</p> <p>Mines can be a potential hazard for communities through the nature of their activities. Mining activities are usually associated with environmental degradation and potential sources of pollution that could threaten the health and living conditions of communities.</p> <p>Major disruptions in the power supply could severely affect water purification plants in many areas where standby generator facilities are not available.</p> <p>Sewerage works have also been identified as a source of</p>	Yes

	pollution during periods of flooding.	
Human Induced/Technological/Transport		
Roads, Air, Rail	<p>Transportation accidents can have serious impacts on lives, the economy and the environment.</p> <p>Road accidents cost the country billions of Rands each year. The Council for Scientific and Industrial Research (CSIR) has estimated the average cost of road accidents in South Africa. The cost of a single fatal accident is estimated at R329 375; a serious injury at R81 992; a slight injury accident at R21 886, and a damage only accident at R15 564. On this basis the total cost of road accidents nationally is in the region of R12 billion per year!</p> <p>The transport of hazardous materials should also be investigated, especially where these routes cross residential and naturally sensitive areas such as wetlands.</p>	Yes

Chapter 4: NATURAL HAZARDS.

Developing countries seem to be the hardest hit by natural disasters. In the last decade 94% of the 568 major natural disasters in the world, and 97% of the related fatalities, occurred in the developing world. The frequency of disaster events also seems to be on the increase, probably as result of increasing population density and possibly because of changing weather patterns (United Nations Development Program, 2004).

People living in developing countries are four times more likely to die in a natural disaster than a person living in a First World country. Poor people are very often also the only victims of disaster. The flooding in the Cape Flats is a good example, as these people live in an area that is prone to flooding because of the area's poor drainage qualities and their living in structures that are susceptible to flood damage (Action by Churches Together, 2002).

In many poor countries development is repeatedly interrupted by natural disasters such as floods, drought and earthquakes. Natural disasters can lead to an increase in poverty and can retard human development. It is also the poor that are normally worst affected, decreasing their chances further of dragging themselves out of the clutches of poverty (World Bank, 2000).

The identification, risk and vulnerability assessment of natural hazards in Madibeng is therefore extremely important in order to put mitigating strategies in place where possible. If the impacts of natural hazards on local communities are not substantially reduced or prevented, it will be impossible to achieve the goals of Sustainable Development.

4.1 FLOODS

Water related damage caused by flooding of rivers and the coast in the United States accounts for over 75% of federally declared disaster events. The Federal Emergency Management Agency (FEMA) estimates that over 9 million households and \$390 billion

worth of property are at risk of flooding in the United States. Thousands of floods occur worldwide each year, making it one of the most common and damaging of all hazards (Federal Emergency Management Agency, 1997).

A flood is a normal event for any river or stream that could occur over a period of time varying from several times a year to once every few hundred years. Floods are caused when excess water from heavy rainfall, snowmelt or storm surge accumulates and overflows the river or stream's normal path onto its banks and adjacent floodplains (Miller, 1997).

Floodplains are lowlands adjacent to rivers, streams, lakes and oceans that are subject to recurring floods. Floods can occur anywhere in a country, any time of the year, day or night. The potential volume of water that could reach the floodplain is a function of the size of the contributing watershed and topographic characteristics such as watershed slope and shape, and climatic and land use characteristics (Coch, 1992).

Several factors determine the severity of floods, including rainfall intensity and duration. A large amount of rainfall in a short time span can cause flash flooding. A small amount of rain can also cause flooding if the soil is saturated from a previous wet period, or if the rain is concentrated in areas where the surface is impermeable, such as in developed areas where most of the surface is covered with concrete, tar and other building materials (Federal Emergency Management Agency, 1997).

Topography and groundcover are also contributing factors for floods. Water runoff is higher in areas with a steep slope and low vegetation density. Urbanization of floodplains and manipulation of stream channels have increased both the frequency and magnitude of floods in many areas. Floods are most common in the season of highest precipitation (Miller, 1997).

The intensity of floods in South Africa is measured in cubic metres per second, and the risk of flooding is defined as the probability of occurrence in a year in percentage or return period (years). Therefore a 50 year flood has a 2% ($1/50 \times 100$) chance of occurring in any specific year. The probability of a 50 year flood occurring once in a 50 year time span is thus calculated at 66% (RAVA, 2002).

4.1.1 Hazard Identification

To identify areas at risk of flooding in Madibeng, the first step was to plot all available watercourses. Figure 4-1 indicates all the major rivers and dams in Madibeng. A review of the questionnaires used in the study indicated that the Crocodile River was historically the main source of flood problems in Madibeng.

One possible reason for this is that the catchment area of the Crocodile River is mostly in the built-up areas of Gauteng. Heavy rain can cause high runoff in these areas and cause the river to flood its banks.

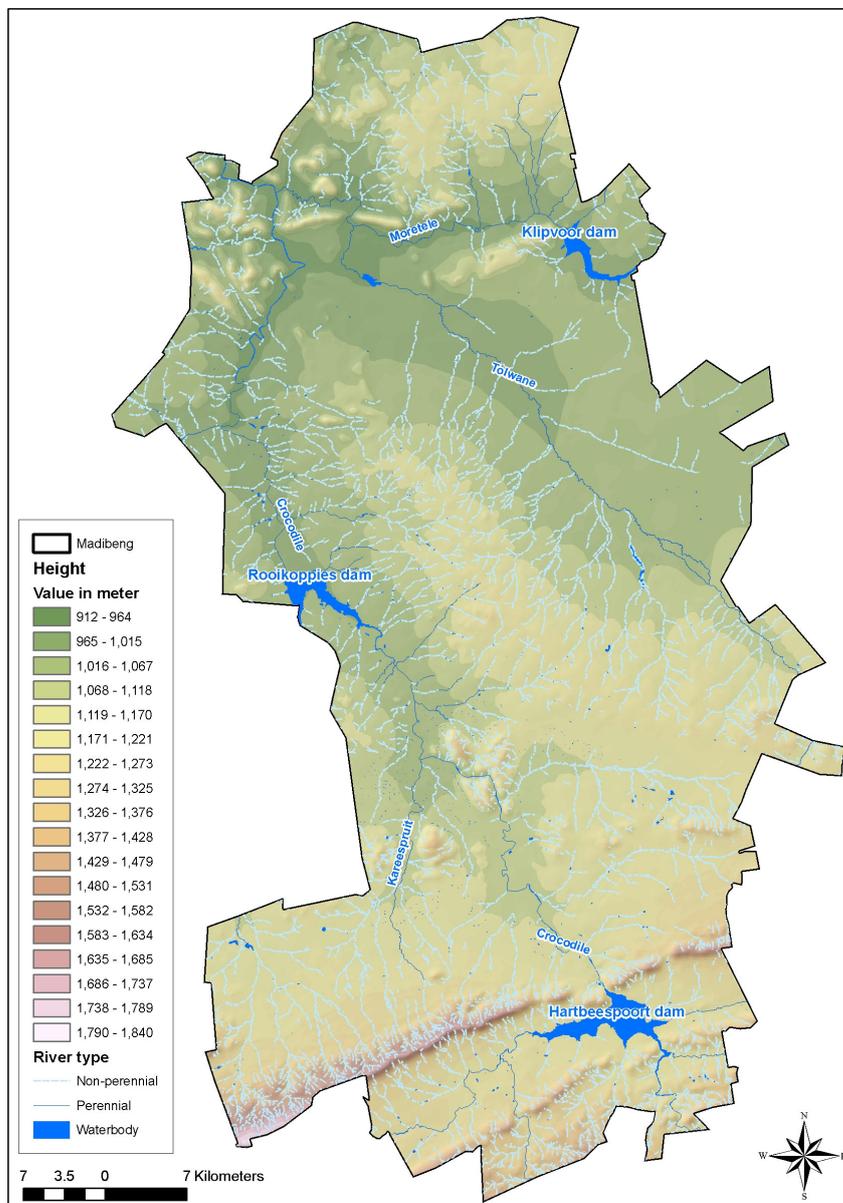


Figure 4-1: Major and Minor watercourses in Madibeng

4.1.2 Risk and Vulnerability Assessment

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There is no digital flood information available on any of the rivers or dams in Madibeng. No data was available that could be used to create flood lines for any of the rivers in Madibeng, even though there have been major flood events in the recent past in this area.

The Department of Water Affairs and Forestry did supply dam failure scenarios for the four major dams that could cause flooding in Madibeng. These scenarios were only available as hardcopy maps and had to be digitised to be used in this study.

The risk and vulnerability assessment of river and dam flooding will be discussed separately:

- Rivers

The National Water Act (Act number 38 of 1998) states: "...no person may establish a township unless the layout plan shows, in a form acceptable to the local authority concerned, lines indicating the maximum level likely to be reached by floodwaters on average once in 100 years".

Although the water act requires that floodlines should be demarcated before a development is approved, there were no flood lines available for Madibeng, and it was therefore impossible to create an accurate flood hazard scenario map for the Municipality. As floods are regarded as a major potential source of a natural disaster, it was decided that an attempt should be made to identify areas where detailed flood analysis will be needed.

In this case the mitigating strategy in preventing flood damage is first of all to apply GIS in the identification of settlements where flooding is likely due to their proximity to watercourses, and then prioritise these settlements according to vulnerability. This method should give an indication of the order in which detailed flood studies should be performed and thereby give Disaster Management some guidelines regarding their budget planning.

Table 4-1 indicates settlements and the distance from their location to perennial rivers. The table also indicates whether the settlement is considered to be rural or urban. As rural settlements have a lower population density, the impact of a flood should be more severe on a more densely populated urban settlement. The table was then sorted by distance from the perennial river and type to identify areas where detailed flood analysis should be performed first. The settlements of Brits, Primindia and Rabokala should have the highest priority for Disaster Management.

Figures 4-2 and 4-3 are examples of the distance buffer used to calculate the distance of the settlements to rivers and to indicate the type of settlement at risk in the study area. Figure 4-2 indicates an urban area within 100 Metres of a river. In the urban areas for which cadastral data are available, it is possible to calculate the number of erven within the flood area as well as the land use of the individual erven. Figure 4-3 indicates a rural area for which cadastral and land use information is generally not available. In these areas it could be possible to calculate the number of buildings at risk by using data from The Chief Surveyor General. It was, however, found that this data set is aged and no longer represents reality in the case of Madibeng and was therefore not used.

Table 4-1: Settlements at risk of flooding

Settlement	Distance from river	Type
Brits	0-100 Metres	1. Urban
Primindia	0-100 Metres	1. Urban
Rabokala	0-100 Metres	1. Urban
Bapong-Legalaopeng	0-100 Metres	2. Rural
Bapong-Nommer 1	0-100 Metres	2. Rural
Bapong-Skoolplaas	0-100 Metres	2. Rural
Hebron	0-100 Metres	2. Rural
Jakkalsdans	0-100 Metres	2. Rural
Klipvoorstad	0-100 Metres	2. Rural
Makanyaneng	0-100 Metres	2. Rural
Marikana	0-100 Metres	2. Rural
Ifafi	100-200 Metres	1. Urban
Meerhof	200-300 Metres	1. Urban
Boikhutsong Informal	300-400 Metres	2. Rural
Jericho	400-500 Metres	2. Rural

Moiletswane	400-500 Metres	2. Rural
Sonop	600-700 Metres	2. Rural
Dipompong	700-800 Metres	2. Rural
Ga-Rasai	800-900 Metres	2. Rural
Schoemansville	900-1000 Metres	1. Urban
Bapong-Newtown	900-1000 Metres	2. Rural
Legonyane-Boots	900-1000 Metres	2. Rural
Madinyane-Ramogatla	900-1000 Metres	2. Rural
Damonsville	More than 1 Kilometre	1. Urban
Mooinooi	More than 1 Kilometre	1. Urban
Mothutlung	More than 1 Kilometre	1. Urban
Oukasie	More than 1 Kilometre	1. Urban
Assen	More than 1 Kilometre	2. Rural
Bapong-Outstad	More than 1 Kilometre	2. Rural
Erasmus	More than 1 Kilometre	2. Rural
Fafung-Phefong	More than 1 Kilometre	2. Rural
Jonathan	More than 1 Kilometre	2. Rural
Kgabalatsane	More than 1 Kilometre	2. Rural
Maboloka	More than 1 Kilometre	2. Rural
Mabopane	More than 1 Kilometre	2. Rural
Madinyane	More than 1 Kilometre	2. Rural
Majakaneng	More than 1 Kilometre	2. Rural
Makgabatloane	More than 1 Kilometre	2. Rural
Mmakau	More than 1 Kilometre	2. Rural
Mmakaunyana Block A	More than 1 Kilometre	2. Rural
Oskraal	More than 1 Kilometre	2. Rural
Rietgat	More than 1 Kilometre	2. Rural
Sephai	More than 1 Kilometre	2. Rural
Shakung	More than 1 Kilometre	2. Rural
Tornado-Modderspruit	More than 1 Kilometre	2. Rural
Vaalboslot	More than 1 Kilometre	2. Rural
Wonderkop Mine	More than 1 Kilometre	2. Rural

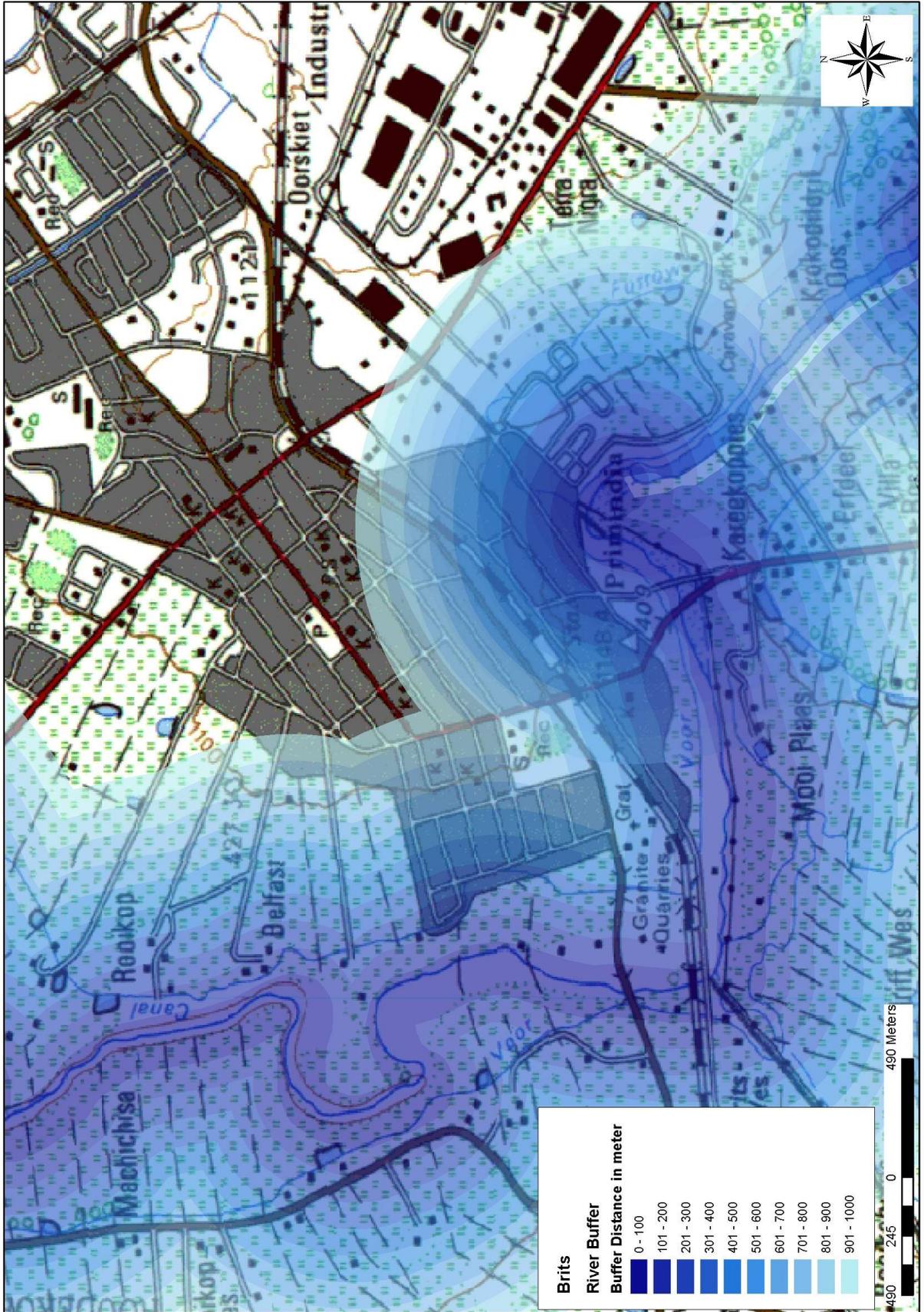


Figure 4-2: Urban flood hazard scenario

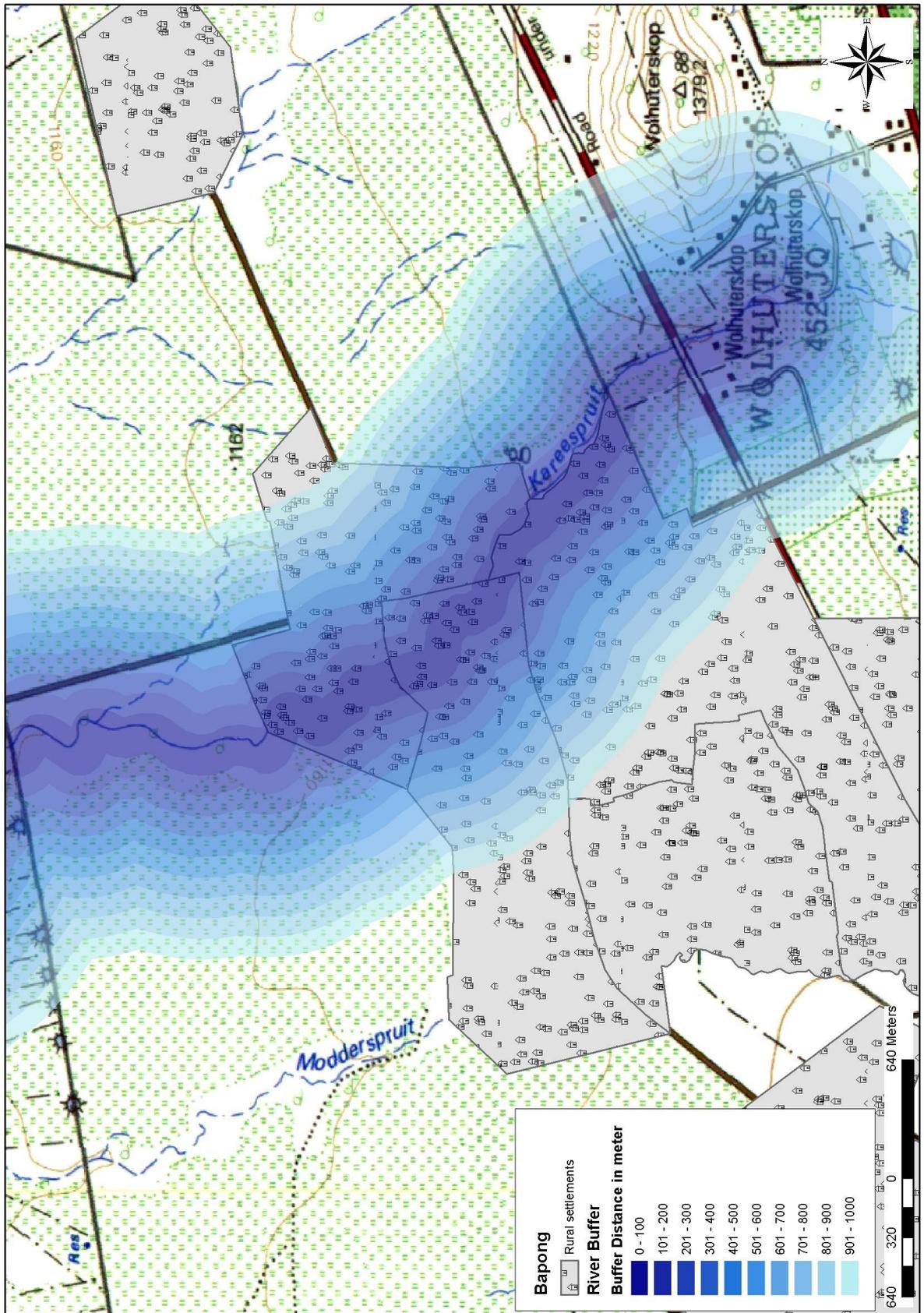


Figure 4-3: Rural flood hazard scenario

- Dam Failure Scenarios

Figure 4-1 also indicates dams in Madibeng, classified by the Department of Water Affairs and Forestry (DWAF) as high risk due to their size. The DWAF has created dam failure scenarios for all high risk dams in South Africa and also keeps a database of dams with information such as the height of the dam wall, capacity and date of construction. This information is important for any local and provincial government to formulate appropriate evacuation plans and policies.

There are three dams in Madibeng that are regarded as high risk by the DWAF, namely the Hartbeespoort dam, Rooikoppies dam and Klipvoor dam. The Vaalkop dam is not situated in Madibeng, but will cause flooding in Madibeng if its wall should fail and is therefore included in this study.

- Hartbeespoort dam failure scenario.

Figure 4-4 indicates the dam failure scenario of the Hartbeespoort dam. The South Western areas of Brits and Primindia are at risk of flooding from this dam. By overlaying information from the surveyor general onto the dam failure scenario it is possible to identify exactly which erven are at risk of flooding in this area.

A total of 557 erven in Brits, mostly for residential, industrial and commercial use, would be inundated should the Hartbeespoort dam wall fail. Unfortunately there was no information available on flow velocity, depth of inundation and property values of the affected erven. Given this information it would also be possible to calculate the possible damage such a flood could cause.

It is also possible to link the valuation roll of Brits to the erven, which would provide information such as the value of each property and the name and telephone number of the owner. This could be valuable information for Disaster Management in the event of an emergency evacuation. Roads and railway lines would also be flooded, but there are enough alternative routes to and from Brits, ensuring that the community would not be isolated during a flood.

Most of the rural flooded area is used for commercial agriculture and is under irrigation. A major incident such as this could cause extensive damage to agricultural infrastructure and crops in the area.

- Vaalkop and Rooikoppies dam failure scenarios.

Figure 4-5 indicates the dam failure scenarios of the Vaalkop and Rooikoppies dams. There are no highly populated areas at risk, but along the river there are commercial farming activities. Damage could be caused to crops and irrigation infrastructure in case of flooding. The R511 from Brits to Thabazimbi would also be flooded and an alternative access route would have to be found.

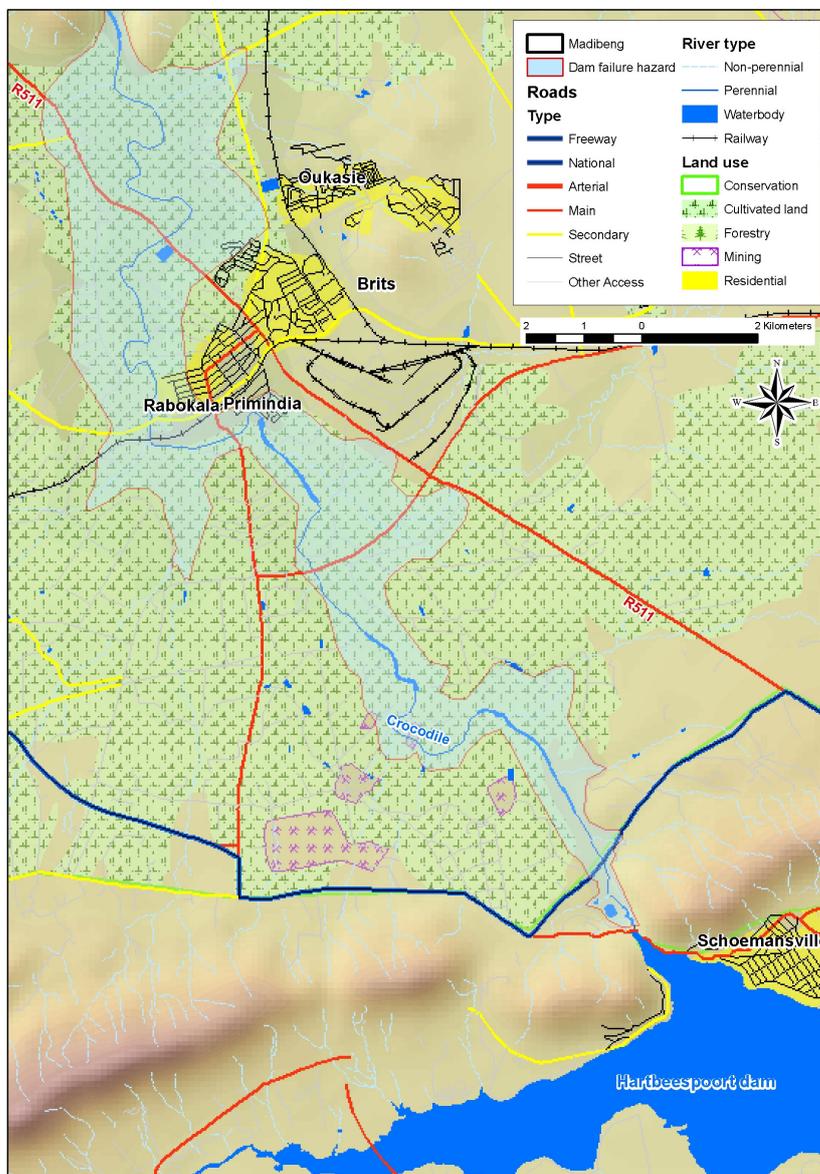


Figure 4-4: Hartbeespoort dam failure hazard scenario.

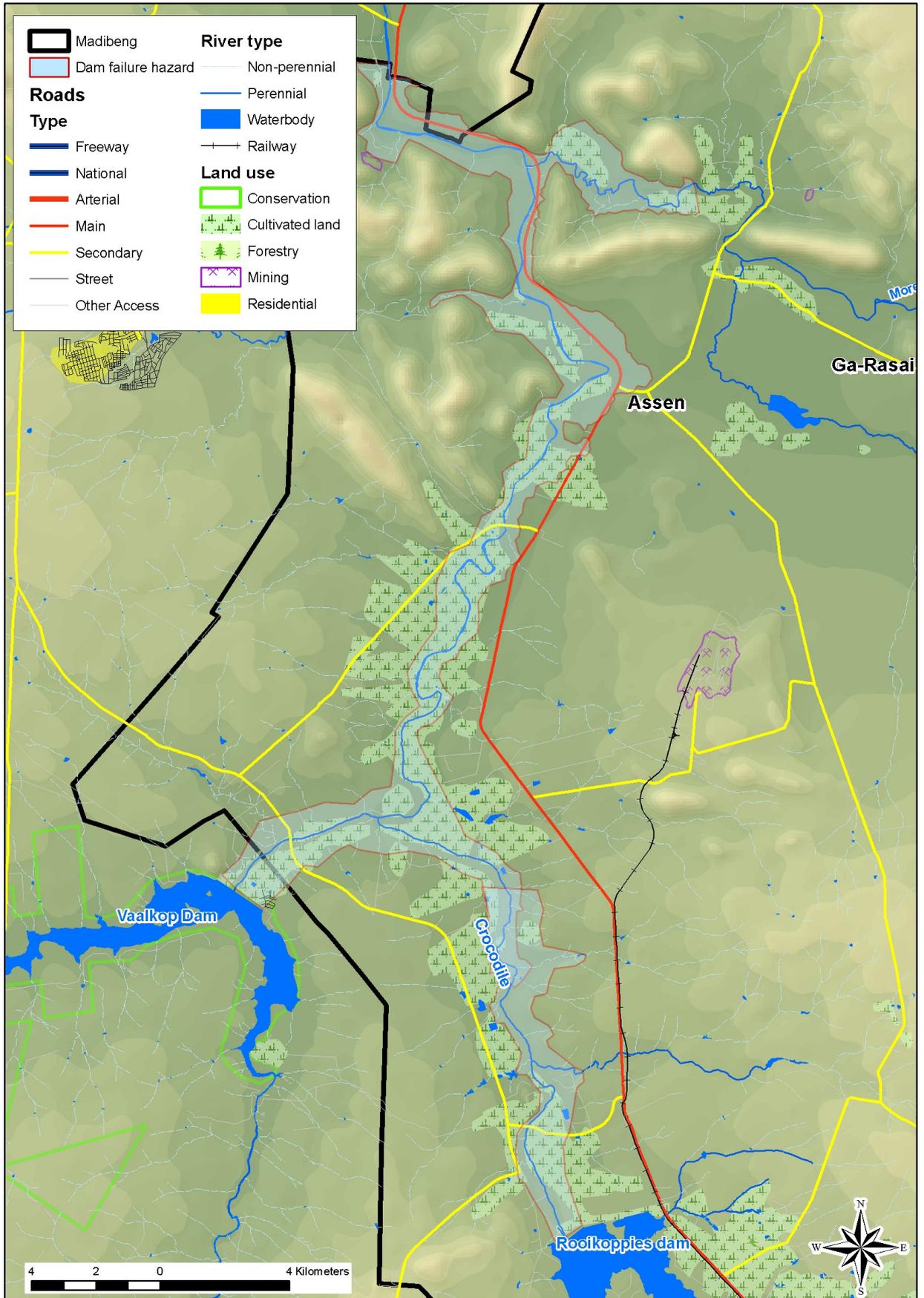


Figure 4-5: Vaalkop and Rooikoppies dam failure hazard scenario

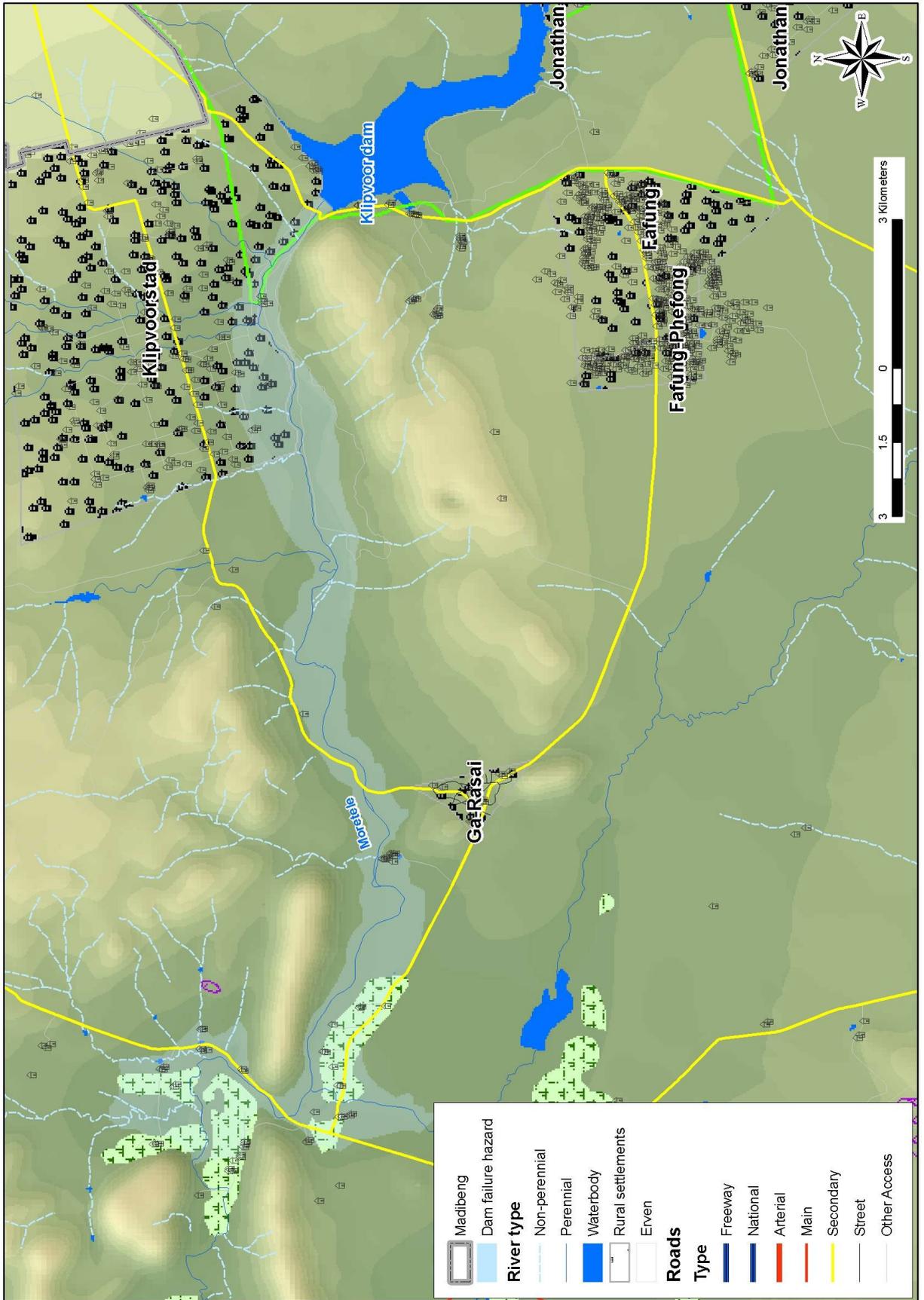


Figure 4-6: Klipvoor dam failure hazard scenario

- Klipvoor dam failure scenario.

Figure 4-6 indicates the dam failure scenario for the Klipvoor dam. The community of Klipvoorstad would be at risk of flooding along the Moretele River. This area used to be a part of Bophutatswana and consists largely of rural settlements. Very little information is available on these areas, making it impossible to assess the risk that this dam poses to the local community.

It is therefore important for disaster Management to gather relevant land use data of the potential area affected by the Klipvoor dam failure scenario.

4.1.3 Conclusions and Recommendations

There are many existing flood prediction systems and models being used around the world. In South Africa there are local experts in floodplain management and flood damage predictions and assessments. The methodologies and local expertise are therefore available for use in Madibeng (Zschau and Küppers, 2003).

For Disaster Management to compile appropriate flood prevention and mitigation strategies, better quality flood and land use information should be generated. In order to prioritise risk areas it is necessary to predict the possibility of loss of life and calculate potential damage to infrastructure.

The most important information in this regard is flow velocity, depth of inundation and better-detailed land use information. This information could be used in a GIS to perform detailed flood hazard and risk assessments that would provide the Disaster Management Manager with the information needed for effective floodplain management.

A flood hazard assessment can be executed by using the velocity of the floodwater in combination with the depth of inundation. The following figure (Figure 4-7) illustrates the basic methodology used for the execution of a flood hazard assessment. Given the velocity and depth of floodwaters it is possible to identify low, medium, high and excessive hazard areas (Booyesen, 2001).

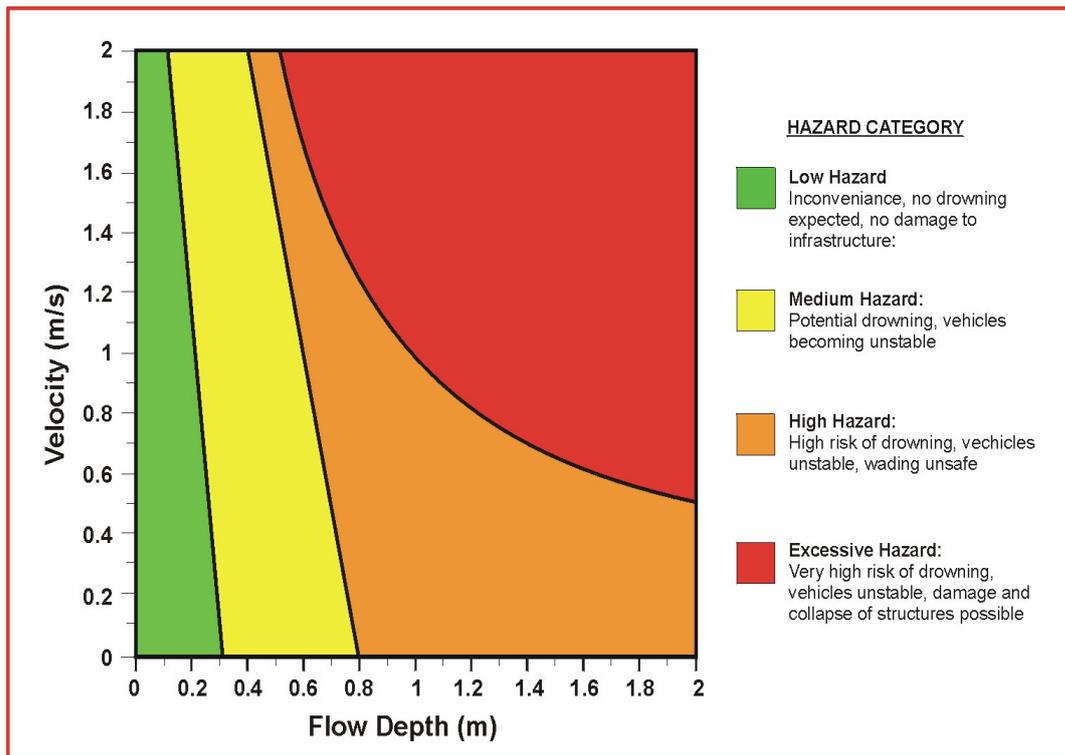


Figure 4-7: Flood hazard assessment (Booyesen, 2001).

Figure 4-7 illustrates that the level of hazard increases with an increase in velocity and depth of inundation. This shows that loss of life and damage to infrastructure becomes more likely as flooding becomes deeper and flow becomes stronger.

Using the hazard assessment it is then possible to execute a risk assessment by evaluating existing land use types in the hazard areas. Recommendations can then be made on the land use types suitable for the different risk areas.

For example, where the risk of flooding is very high, the land would be more suitable for activities that do not require large developments or large concentrations of people. Parks and golf courses are good examples of land use types that are more suitable for areas at risk of flooding. Schools, hospitals and old-age homes are examples of land use types that should be located in areas where the risk from flooding is minimal, as the people in these facilities are especially vulnerable during a flood.

4.2 VELD FIRE

Periodic fires are natural phenomena of our environment, as natural and as vital as other phenomena such as rain, snow or wind. Veld fires occur all over the country and can have a devastating impact on people's lives and the environment itself. Uncontrolled and damaging fires are a common occurrence in South Africa, especially during warm and dry conditions.

The development and behaviour of a veld fire depends mainly on three contributing factors, namely: fuel, weather and relief (Skidmore, 2002).

- Fuel:** Veld fires require fuels in the form of vegetation that can burn. The potential fuel load for a fire can be expressed in tons per hectare and basically consists of the amount of vegetative material available. If the fuel load doubles, the energy released by a fire can also be expected to double (PHE). Different fuels have different burn qualities. Some materials burn more easily, longer or more intensely than others. Table 4-2 is an example of a vegetative fuel classification, which gives the fuel load and burning intensity for different plant types. Another essential factor is fuel moisture. Like humidity, fuel moisture is expressed as a percentage of total saturation and it varies with weather conditions. Low fuel moisture levels are more conducive to burning than high moisture levels.

Table 4-2: Vegetative fuel classification (Van Wilgen, 1997)

Vegetation	Fuel Loads	Fire Intensity
Type	Gm⁻²	KWm⁻¹
Savanna / Grassland	100 - 1000	10 000
Fynbos	1000 - 3000	20 000 - 30 000
Pine plantations	18 000 - 40 000	No data
Acacia Cyclops (Rooikrans)	9000	20 000 - 60 000
Eucalyptus plantations	42 000	No data
Australian Eucalyptus	> 21 000	60 000
North American Pine	1500 - 5000	60 000 - 100 000

- **Weather:** Seasonal climatic patterns have a major influence on the season during which fires occur in a given region. For example, fires are most frequent and intense in Mediterranean climate ecosystems late in the summer, when fuels are most dry. In other areas, seasonal variations in fire behaviour arise from changes in both fuel and climate. For example, on the southeastern coastal plain of the United States, fires are most frequent in the fall and spring due to a combination of three- to four-week droughts and an accumulation of dead fuels during this period. Fires may also occur during the summer, however fuels tend to be green and not conducive to spread or high intensity burning (Crutzen and Goldammer, 1993).
- **Relief:** Relief can have a powerful influence on fire behaviour. The movement of air over the terrain tends to direct a fire's course. A kloof can funnel air upward and act as a natural chimney, intensifying fire behaviour and inducing faster rates of spread. Aspect also has an influence as solar heating of drier, north-facing slopes produces upslope thermal winds that can also complicate fire behaviour (FEMA, 1997).

Slope also has a big influence on the spread of fire. Each 10 percent increase in slope doubles the rate of spread of a veld fire. On steep slopes, fuels on the uphill side of the fire are pre-heated and dried, thus intensifying fire behaviour in that direction. A fire can rapidly ascend cliff faces if sufficient fuel is available.

Terrain can also inhibit the spread of fire as fire travels much slower downhill than uphill and ridge tops very often mark the end of a veld fire's rapid spread (RAVA, 2002).

Any fire also needs a source of ignition. Lightning is the main natural source of ignition of vegetation. During summer months, fires caused by lightning may burn small areas before being extinguished by rain. However dry electrical storms are a serious hazard, especially during dry periods as these storms can cause numerous fires over an extended area (RAVA, 2002).

The main source of fire ignition however is human intervention, either through arson or accidents. In the United States the U.S. Forest Service (USFS) calculated that 25.7

percent of local veld fires reported were caused by arson. Other ignition sources were debris burning (24 %); lightning (13.3 %) and other (16.7 %) (FEMA, 1997).

Urban encroachment into natural areas, in conjunction with forest and wild land fire suppression policies, has increased the frequency and intensity of large area fires in many parts of the world. Aggressive fire suppression actions in many areas have led to a situation in which vegetation density and resulting fuel loadings have reached unprecedented levels. The result is that when fires do occur, they show more unfamiliar behaviour, are more intense and damaging, and thus more difficult and costly to suppress (FEMA, 1997).

4.2.1 Hazard Identification

According to the National Veld and Forest Fire Act, Act number 101 of 1998, the Minister is responsible for the development and application of a fire danger rating system for the prevention of veld fires. The fire danger rating system has to take into account the specific characteristics of an area, including; topography, plant types, seasonal climate changes, typical weather conditions, current weather conditions, predictable weather conditions and any other applicable factors.

There are six active weather monitoring sites in Madibeng, all concentrated in the southern part of the Municipality. It was therefore decided that data obtained from these sites would not be representative of the whole Municipality. The general climatic characteristics of the region were considered in this report.

Temperatures in Madibeng vary between extremes of -6 degrees Celsius in winter to 40 degrees Celsius in the summer months. Daytime wind speeds regularly exceed 5 metres per second with the main wind direction being westerly and north-westerly. During night-time the wind becomes a predominantly easterly and north-easterly (SA Weather Service).

Rainfall in Madibeng is seasonal with most of the precipitation received in the summer months. Rainfall can be very erratic and variable at times, causing occasional periods of

extreme wet or dry conditions. As can be seen on Figure 4-8, average rainfall varies from 725mm in the south to around 575mm in the north-west (Van den Berg and Manley, 2002).

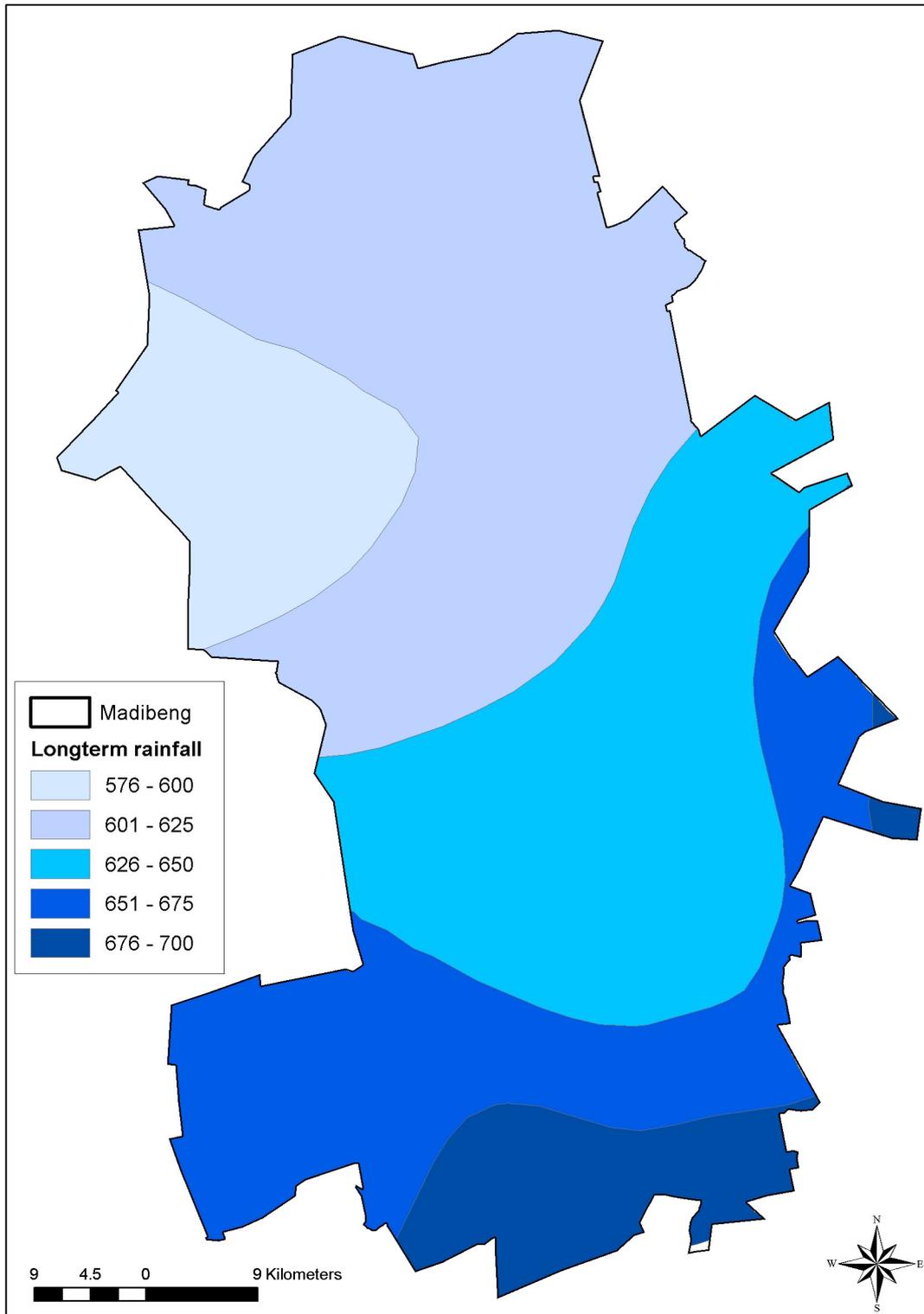


Figure 4-8: Average rainfall in Madibeng (mm per annum).

Madibeng therefore has a relatively average rainfall and high temperatures that can contribute to substantial vegetative growth in good seasons, providing the fuel needed for fire. The only other factor needed then is an ignition event, which could be provided by lightning from the characteristic Highveld thunderstorms in summer.

On the other hand, summer months are also the months with the highest average precipitation and therefore the moisture content of fuels is higher. Christensen proved that on many landscapes fire frequency is determined less by ignition events than by fuel and landscape conditions that determine fire spread. Fires tend to be most frequent in dry conditions that favour fuel accumulation (relatively high rates of fuel production, and/or slow decomposition) and occasional dying of fuels. Although fuel production may increase during the moist season, high fuel moisture content limits fire occurrence (Whelan and Whelan, 1995).

This is exactly the scenario for the Madibeng Municipality. The region is situated in a relatively average rainfall area with enough precipitation even for forestry needs. Therefore rainfall in the area is sufficient during the wet season to support substantial plant growth, increasing the potential fuel loads for veld fires. During the dry season the moisture content of the fuels decreases and some species die, creating a high fuel load with low moisture content.

Fire ignition is more likely during warmer months, when the temperature of fuels is higher and there is a higher likelihood of the occurrence of thunderstorms and associated lightning. However, even though lightning is the most common form of natural ignition, research has found that the correlation between the occurrence of thunderstorms and fire frequency in the USA is very weak in most areas (Pyne, 1997).

The most common source of fire ignition is human intervention. FEMA found that four out of five veld fires in the USA were caused by humans. Given this fact and the fact that human activity is not seasonally bound and very difficult to predict, it can be stated that the likelihood of fire ignition is just as high in warm as in cold months.

In the case of the Madibeng Municipality it was then decided to identify the dry months of August and July as the months that hold the greatest risk of veld fires, based on the

relatively high potential fuel load and low moisture content of the fuel. According to local stakeholders, these months are also prone to strong winds that could accelerate the spread of fire.

Wet months in Madibeng are the months of September to May, and these months are dominated by relatively high rainfall, high temperature and high relative humidity, not suited to large veld fire events.

4.2.2 Risk Assessment

During 1988, South Africa passed the new National Veld and Forest Fire Act (Act 101 of 1988). The act provides for the prevention of veld, forest and mountain fires through the deployment of a National Fire Danger Rating System (NDFRS) (Section 3 of the Act).

An NDFRS will allow for the prediction of potentially hazardous conditions conducive to large and potentially damaging veld fires. This will allow for preventive measures to be taken to reduce both the risk of unwanted ignition, and to increase the state of readiness for dealing with wild fires. The NDFRS should be regarded as one of the early warning systems required by the National Disaster Management System.

This fire danger rating system must:

- a) Take into account the relevant peculiarities of each region, including-
 - i) the topography;
 - ii) the type of vegetation in the area;
 - iii) the seasonal climatic cycle;
 - iv) typical weather conditions;
 - v) where reasonably possible, current weather conditions;
 - vi) forecasted weather conditions, and
 - vii) any other relevant matter;

- b) Incorporate the formula or formulae needed to:
 - i) take into account all factors affecting the fire danger for each region;
 - ii) calculate the indicators needed to rate the fire danger;
 - iii) rate the fire danger in each region for an appropriate period or periods.

This report provides an account of the process used to calculate the fire danger index employed in the calculation of fire danger for Madibeng with the available weather data, and it further provides an overview of the main parameters, which can affect fire ignition and danger.

Methodology:

As with all the other reports in this study, the fire danger map was compiled using only existing data and the inputs of several affected parties. The following key role-players were consulted in the development of a fire danger map for Madibeng:

- The Madibeng Fire Brigade.
- The South African Weather Bureau (SAWB). Weather is strongly associated with the mechanisms of fire behaviour. Wind speed strongly affects heat transfer (due to flame tilt) and convectional heat transfer; fuel combustibility and heat loss rates depend strongly on moisture content; fuel primarily acts as the burn substrate, providing the heat of combustion for the fire, and heat loss rates depend strongly on fuel moisture content.
- The Ward Councillors of Madibeng.
- The Institution of Soil and Climate and Weather in Pretoria (ISCW).
- The Agricultural Department of the University of the Free State.
- The Department of Water Affairs and Forestry (DWAF).

As required by the National Veld Fire and Forest Fire Act, the fire danger rating system should have the primary purpose of preventing and controlling wild fires. This prevention should come about through the ability to identify the conditions that would lead to dangerous fires. Fire danger is the result of both relatively constant (fuel, relief) and variable factors (weather) affecting the fire's inception, spread, difficulty to control and potential to damage.

Madibeng Municipality is divided into 30 wards and the area has a wide range of climatic conditions and land cover types ranging from natural grassland to woodlands. Using the available land cover information on Madibeng, received from ENPAT, four different land cover categories were identified for Madibeng with a view to compiling a Fire hazard map, see Table 4-3.

Table 4-3: Categories of different land covers (fuel loads) and the relief of Madibeng.

Land Cover (Fuel)	Category	Slope	Risk
Built up- industrial Built up-residential Mines and quarries Built up commercial	1	Steep Medium Flat	Medium Medium Low
Grass Natural Grassland Subsistence farming	2	Steep Medium Flat	High High Medium
Bare rock Eroded land Degraded land	3	Steep Medium Flat	Medium Low Low
Plantations Indigenous forest Thicket Bushland Woodland	4	Steep Medium Flat	High Medium Low

- The first category is land cover types that are seen in this report as areas with a low fuel load, which is mostly urban areas where a relatively high percentage of the surface is covered with materials such as concrete and tar that do not burn easily.
- The second category is land cover types with a high fuel load that would also have a low moisture level during dry climatic conditions.
- The third category is land cover types with very low fuel loads, as vegetative growth is minimal in these areas.
- The fourth category is land cover types with a high fuel load and relatively high moisture content. Tree canopies can have a dramatic impact on fire risk because they tend to keep soil and vegetation moist and shield an area from wind. Plantations are also normally managed in such a way as to reduce the risk of fire (Greene, 2002).

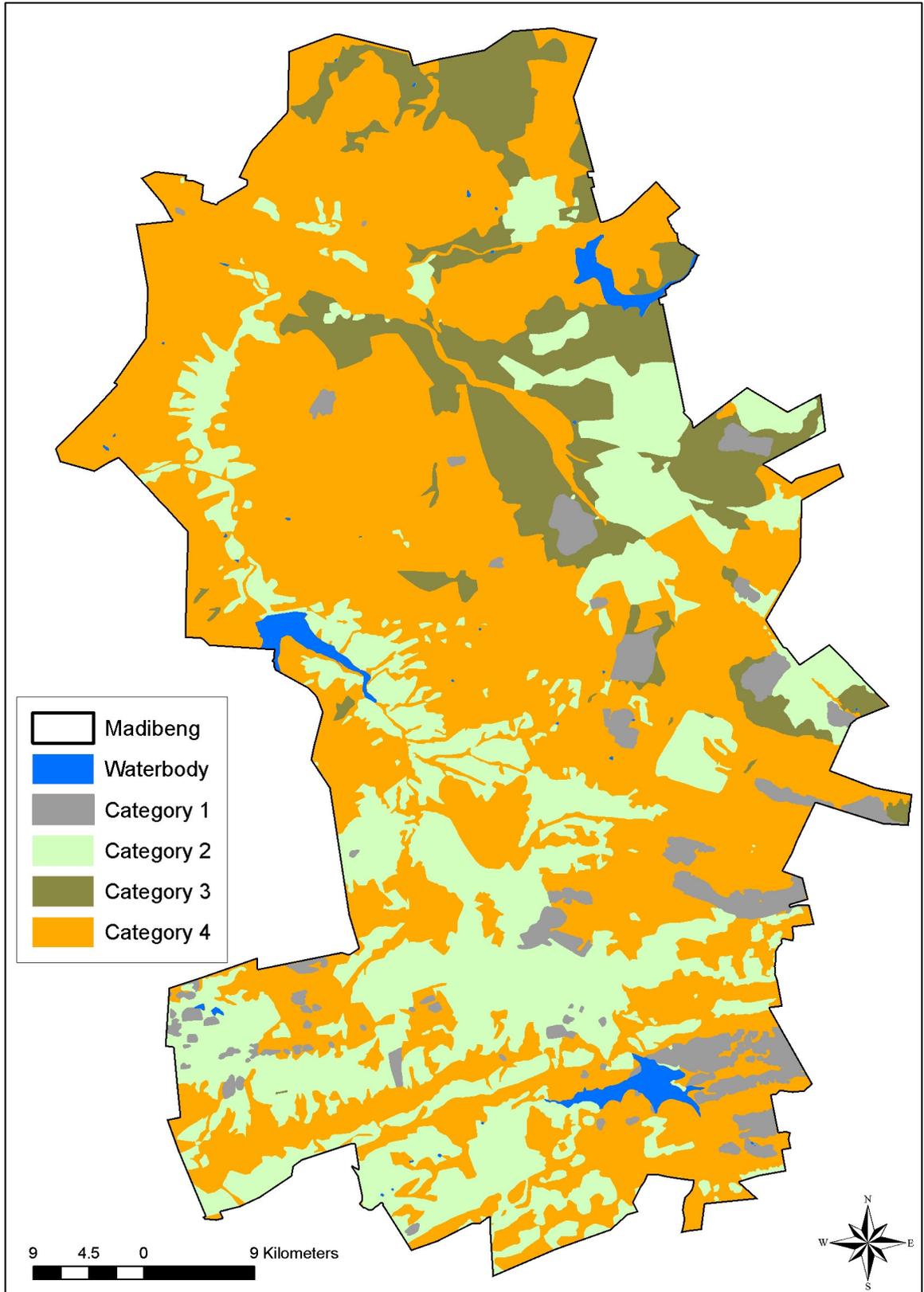


Figure 4-9: Madibeng fuel categories.

Figure 4-9 is the result of merging the land cover types in Madibeng into four fuel classes according to the perceived fuel load of each land cover type. Firstly, most of the Municipality's land cover is considered to have relatively high fuel loads that could cause serious fire hazards, especially during dry periods.

Secondly, Madibeng was divided into areas of steep, medium and flat slopes, again using available information received from the Environment and Tourism Potential Atlas (ENPAT) of South Africa. The slope classes were then compared to the different fuel loads, also in Table 4-3, and the risk associated with each combination of fuel and slope, according to Professor Frank Nwonwu of the Agriculture Department at the University of the Free State, is given in the risk column.

Using the values in Table 4-3 it was then possible to compile a fire hazard map for Madibeng, indicating areas of high, medium and low risk. Areas with relatively high fuel loads situated on steep slopes were regarded as high risk, while low fuel loads situated on flat surfaces were regarded as low risk.

The map produced for this study can be regarded as a worst case scenario, as risk was calculated assuming that fuel loads were high and moisture content low. This set of conditions would be most likely during the months of July and August.

Figure 4-10 indicates that areas covered by grass and located on steep slopes are fire prone and therefore classified as high hazard areas, as opposed to areas situated on moderate to flat slopes. This is because steep slopes significantly increase the forward rate of spread of fires and modify the extent to which materials ahead are pre-heated. The combination of steep slopes and high fuel loads creates a high fire hazard, whereas areas situated in moderate to flat slopes with smaller fuel loads have a lower hazard rating.

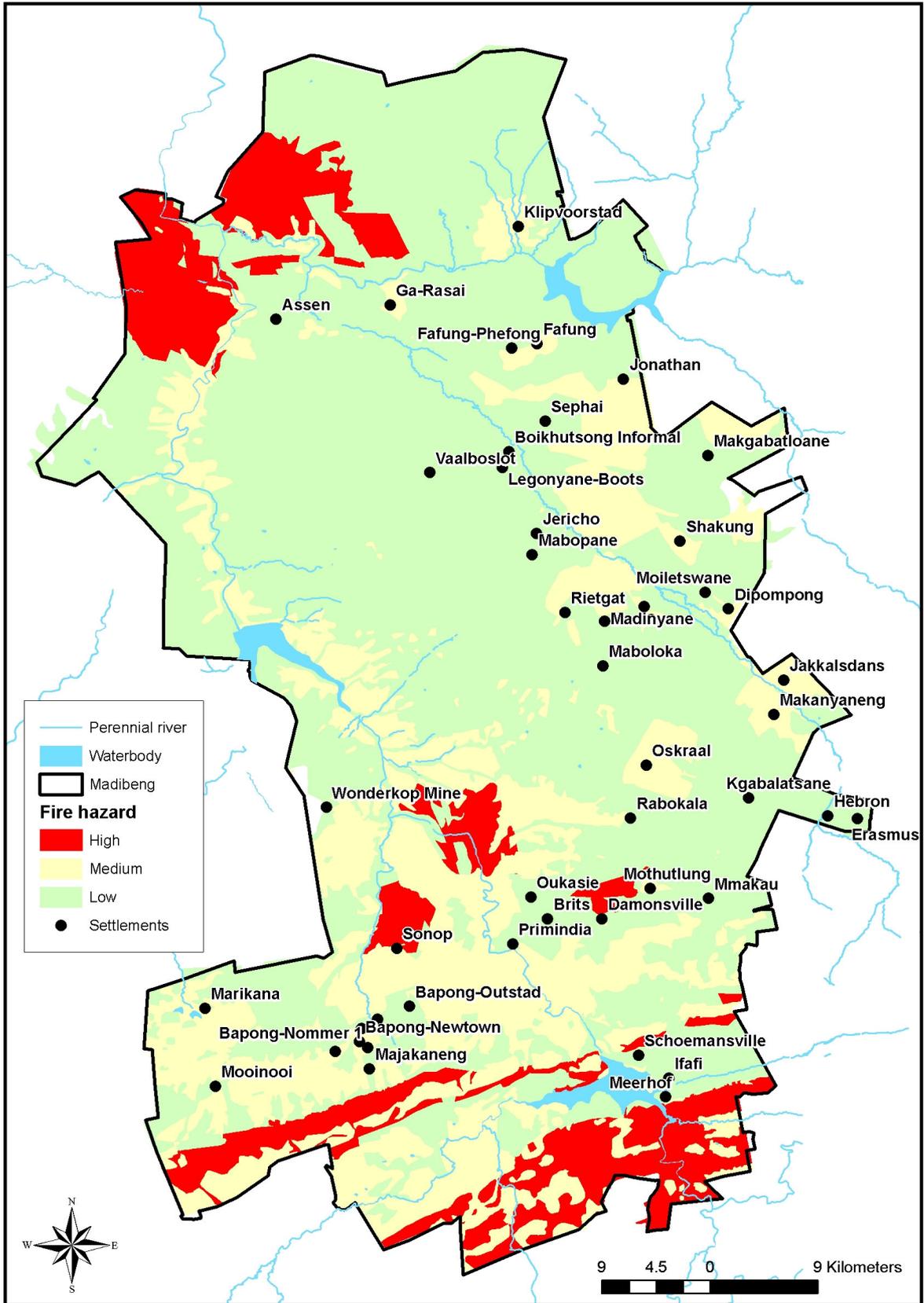


Figure 4-10: Fire hazard map for Madibeng

4.2.3 Vulnerability Assessment

Using GIS it is possible to identify communities at risk by overlaying a map of settlements in Madibeng with the fire risk map. Areas that are within 500m of a high-risk fire area were then identified. The following communities indicated in Table 4-4 are vulnerable to veld fire.

Table 4-4: Communities at risk of veld fire

High Risk	Medium Risk
Brits	Bapong-Legalaopeng
Damonsville	Bapong-Newtown
Majakaneng	Bapong-Number 1
Meerhof	Bapong-Skoolplaas
Mmakau	Damonsville
Mothutlung	Dipompong
Schoemansville	Fafung
Sonop	Ga-Rasai
	Jakkalsdans
	Jonathan
	Klipvoorstad
	Makanyaneng
	Marikana
	Mmakaunyana Block A
	Mothutlung
	Oskraal
	Rabokala
	Shakung
	Sonop
	Tornado-Modderspruit

As illustrated on Figure 4-10, the majority of communities are situated in the medium to low fire hazard areas. The reason for this is that very few communities are situated on areas with a steep slope, as building costs are very high in such areas.

However, there are areas around the Hartbeestpoort dam that are situated on steep slopes. These are mainly expensive properties, built for the aesthetic value associated with the view of the dam and surrounding area.

Since the combustion rate of any fuel is positively influenced by rate of oxygen supply, wind, by renewing oxygen supply, will affect fire behaviour. Wind also affects the angle of the fire front (head fires) pre-heating fuels in the direction the wind is blowing and increasing the rate of spread in that direction.

Wind can also spread a fire by blowing and distributing burning particles to other areas, making fire mitigation very difficult. Structures made from materials that are susceptible to fire, such as thatched roofs, are at high risk. Unfortunately no detailed information is available on the types of structures in Madibeng. This made it impossible to identify areas that are vulnerable to fire due to construction type, even though it was indicated that there are informal settlements in Madibeng where traditional houses with thatched roofs do exist and also structures built with materials such as wood, which could be vulnerable to fire.

- Emergency services

The fact that most of the settlements are situated relatively far from emergency services increases these communities' vulnerability to fire. According to the Fire Brigade, areas that are situated 30km and more from emergency services are highly vulnerable to fire if precautionary steps are not implemented.

4.2.4 Conclusions and Recommendations

- Communication of the fire danger

Fire protection associations should be implemented in order to assist with the collection of data, and the calculation and prediction of the fire danger. These associations can help communicate fire warnings to affected communities.

A communication strategy for the general public should be implemented, which must include not only the fire danger rating system, but also preventive measures and actions to be taken in case of an emergency.

- Administration of the fire danger

Fire protection agencies should be established in terms of the act, and should have responsibilities for co-ordinating activities relating to the prevention and combating of fires in their areas of jurisdiction. The Disaster Management Centre should function as a repository and centre of information concerning fire management. In terms of the Act, the communication of predicted high fire danger through broadcasts and publication in newspapers is compulsory.

Studies of the relation between fuel characteristics, weather conditions and fire behaviour can provide Disaster Management with very useful information to formulate realistic guidelines for fire management in areas with different physical characteristics.

Unfortunately a detailed accurate fire management system can only be possible if sufficient reliable information is available to the Disaster Management Manager. These results still need to be verified and cannot yet be generalized as a fire hazard map for Madibeng. Fire danger indexes need to be interpreted in terms of the risk of fires occurring, the number and size of fires that could be expected under certain conditions; their relative ease or difficulty to control, and the estimation of possible damage.

In Madibeng at present, no information is available on fire risk. Climatic data obtained from the six weather stations, which are all situated in the same part of Madibeng, is not in a suitable format for relating to fire danger indices.

It is important to keep an accurate database with both historic and present information on fires and the contributing factors that cause fires. For example, the older a fire prone vegetation type is, the higher the veldfire hazard would be under certain climatic conditions, as regular fires prevent the accumulation of dead plant material. Thus it is important to know when last a certain area burned.

Fire protection associations should be developed in order to collect basic data on the occurrence, severity, and duration of fires. It is therefore recommended that further research be undertaken in this regard.

The following information would be highly valuable for the prediction of veld fires in the Madibeng Municipality:

- **Contour lines for the creation of a Digital Elevation Model (DEM):** accurate digital elevation models could be used with spatial analysis software to derive the slope and aspect of an area. The current slope information is not accurate enough, as it was created using contours with a 20 metre interval. The smaller the contour interval used, the more accurate the study terrain will be represented and the more accurate the results of a fire hazard assessment will be. Aspect could also be included in a fire hazard assessment, as it is known that fire risk is higher on north facing slopes in the Southern Hemisphere.
- **Satellite imagery:** Up to date satellite imagery could be used to calculate and update potential fuel loads more accurately by using vegetation indexes, mapping burnt areas and determining fuel moisture levels.
- **Weather data:** Better weather data will enable fire experts to predict weather conditions conducive to fire more accurately. Information such as wind speed and direction and humidity levels could also be used on a daily basis in a fire hazard model.

4.3 DROUGHT

Drought as a disaster causing natural hazard has had the greatest influence on the natural world in the past. It destroys livelihoods and causes entire civilizations to collapse. Drought that only lasts for a year or two can have disastrous effects locally, but if it lasts for many years, it can have devastating effects on the agriculture and water supplies of a whole region.

In some areas of the world, the effects of drought can be extremely severe. In the Horn of Africa the 1984–1985 drought led to a famine which killed 750 000 people. The immense size of the region affected, together with the extreme severity of the drought, made it one of the most significant climatic events of modern times (Glantz, 1987).

Drought is a very common hazard in all parts of the world. Most societies have adapted to cope with the impacts of drought and developed strategies to mitigate its impacts. Drought can be seen as a slow onset hazard, which is easily identifiable, but even so it very often leads to disaster scenarios (Scoones, 1996).

The 1991/92 drought in Southern Africa is a good example of a large scale natural disaster that led to very few deaths. It is estimated that 17-20 million people were at risk of this drought, yet the only casualties of famine were reported in Mozambique where an ongoing civil war worsened the impacts of the drought (De Rose *et al.*, 1998).

Drought can have a variety of impacts, directly influencing people's lives through food shortages or through the economy. The direct impact of drought is first felt in the farming communities, and as agriculture is an important element of any country's economy, the effects of drought soon have a ripple effect through the rest of the economy (Scoones, 1996).

For many households in Southern Africa, agriculture is the primary source of income as well as the main source of subsistence. Due to the unpredictability and variability of South Africa's climate, many potential negative effects can influence agricultural production. Risk and uncertainty therefore dominate the lives of communities living in

dry land areas, because for them drought is a potential climatic hazard that could severely influence their ability to meet their own needs (World Bank, 2000).

This does not have to be the case, however, as new technologies and experience, nowadays enable decision-makers to be able to manage the impacts of drought hazards in such a manner as to avoid or mitigate their potential impacts on a local community. Careful monitoring of drought can ease its effects, allowing people to take early actions that prevent harsh impacts later. However, communities would have to be informed and educated regarding drought mitigation strategies and information provided needs to be up to date and accurate in order to reduce the potential impacts of drought (Garcia and Escudero, 1982).

Based on these facts it is clearly of utmost importance that updated information be kept on critical factors such as rainfall, temperature, land use, infrastructure (availability of roads, processing units and markets), number of livestock, etc. The availability and quality of such data provide the cornerstone for developing accurate risk assessment models and mitigation strategies.

Potential impacts of drought.

Each drought produces a unique set of impacts, depending not only on its severity, duration, and spatial extent, but also on ever-changing social conditions. One of the challenges of planning for drought is to understand the impacts of a drought, both direct and indirect. The impacts of drought are commonly referred to as direct or indirect hazards. Reduced crop, rangeland, and forest productivity, increased fire hazards, reduced water levels, increased livestock and wildlife mortality rates, and damage to wildlife and fish habitat are a few examples of direct impacts (Wilhite, 1998).

The consequences of these impacts illustrate indirect impacts. For example, a reduction in crop, rangeland, and forest productivity may result in reduced income for farmers and the agricultural sector, increased prices for food and materials, unemployment, reduced tax revenues because of reduced expenditures, increased crime, foreclosures on bank loans to farmers and businesses, migration, and disaster relief programs (De Rose *et al.*, 1998).

Direct or primary impacts are usually biophysical and easy to assess. The further removed the impact from the cause, the more complex the link to the cause becomes and, as is the case with any disaster, it becomes more and more difficult to calculate the impact of a drought quantitatively (Mortimore, 1998).

The impacts of drought can be categorized as economic, environmental or social:

- Economic impacts include the loss of income for farmers, which can have a ripple effect in the affected area's economy. Retailers and suppliers, who provide goods and services to farmers, face reduced business. This leads to unemployment, increased credit risk for financial institutions and loss of tax revenue for local, provincial and national government
- Environmental losses can be the result of damage to plant and animal life, wildlife habitat and reduced air- and water quality. Indirect impacts could be an increase in veld fires, degradation of the environment and loss of biodiversity.
- Social impacts mainly involve public safety, health, conflicts between water users, reduced quality of life and inequities in the distribution of impacts and disaster relief. Many of the impacts specified as economic and environmental have social components as well. It is very often the rural poor that are hardest hit by drought and these people are also most disrupted during a major drought event (FEMA, 1997).

Drought impacts are very often ignored in the process of development planning. When drought strikes as it invariably does, the result is a hurried and sometimes inadequate relief response that is in contrast with the ideals of sustainable development (Scoones, 1996).

4.3.1 Hazard Identification

In general, drought is defined as an extended period of deficient rainfall relative to the statistical multi-year average for a region. There are many more specific drought definitions used around the world that are defined according to the lack of rain over various time periods, or measured impacts such as reservoir levels or crop losses (Glantz, 1987).

Drought can be defined in several different ways. Drought always implies a reduction in rainfall, but this reduction can have variable impacts depending on the length of the drought and the deviation from the expected or average rainfall of an area. Drought can therefore have several different definitions:

- **Meteorological drought** is usually identified when there is a reduction in the expected or average rainfall of an area.
- **Hydrological drought** implies a deficiency in ground and surface water conditions, often linked only indirectly to rainfall because of interregional water transfers by rivers or pipelines or storage in dams or reservoirs.
- **Agricultural drought** is a deficiency defined in relation to a particular crop and its requirements. For example, we know how much rain is needed to produce a certain amount of a specific crop type and any rainfall less than that expected or outside the specific crop's growing season, would lead to a drop in production.
- **Ecological drought** is a situation in which the rainfall is insufficient to support normal growth of the natural vegetation (Mortimore, 1998).

The seriousness of drought is a function of the amount of rainfall, effectiveness of rainfall, timing of rainfall, the length of dry spells, the geographical extent and expectations of the community and, most importantly, the management strategies in place to cope with these adverse conditions.

4.3.2 Risk Assessment

From an agricultural and meteorological interpretation, risk is a complicated term that describes the uncertainty of outcome for specific farming enterprises and even for combinations within an enterprise, such as plant variety, planting date, planting density, etc (Van den Berg and Manley, 2002).

The productivity of resources in dry land areas such as the Northern parts of Madibeng, is highly dependant on the trade-offs between available soil moisture and fertility, determined by a combination of rainfall patterns, soil properties and landscape formation. Crops respond differently to rainfall on different types of soil. For example, areas with a high clay content will need higher rainfall to achieve the same infiltration

rates as sandy areas, but on the other hand, sandy soils usually have fewer nutrients than the heavy soils.

These differences in the transport and deposition of nutrients and water across the landscape mean that different areas have different potentials for agriculture. Scientists can use this data in statistical techniques combined with historical drought information to construct models to predict future conditions for specific agricultural activities. They can then create risk forecasts of specific activities up to several seasons ahead of time based on past events and the current physical properties of an area (FEMA, 1997).

Using historical data of the region being studied is the only method of assessing the risk that climatic factors pose for agriculture. In addition to a lack of geographically representative and historical data, the effect of climate change can also disrupt the risk profile of an area. It is therefore very important also to determine the effects of climate change (if any) on all the farming enterprises in an area to ensure that an accurate drought risk assessment can be compiled (Van den Berg and Maley, 2002).

The following drought related information was received from Johan van den Berg of Envirovision for the drought risk assessment of Madibeng:

- **Rainfall**

Rainfall in Madibeng, as in most areas, is not only sharply seasonal, but also variable both during years and seasons. This variability bears an element of risk for all ecosystems, wild and domesticated (Mortimore, 1998).

Rainfall patterns are characterized by unpredictable variability. However, these levels appear to follow a cyclical pattern in Southern Africa with a periodicity of between 13 and 19 years, possibly related to the El Nino-Southern Oscillation effect. The likelihood of shifts in weather patterns in Southern Africa due to global warming is also still undetermined, but a very real threat as extreme weather conditions are likely to increase (Scoones, 1996).

The annual average rainfall for Madibeng can be seen in Figure 4-8. From this it is evident that the annual average rainfall in the Municipality ranges from about 576 mm (light blue areas) in the north-western areas to nearly 700mm (dark blue) in the southern to south-eastern parts.

The different rainfall classes indicated in Figure 4-8 were grouped into three more general rainfall classes that are shown in Figure 4-11. These classes were then named as above average, average and below average.

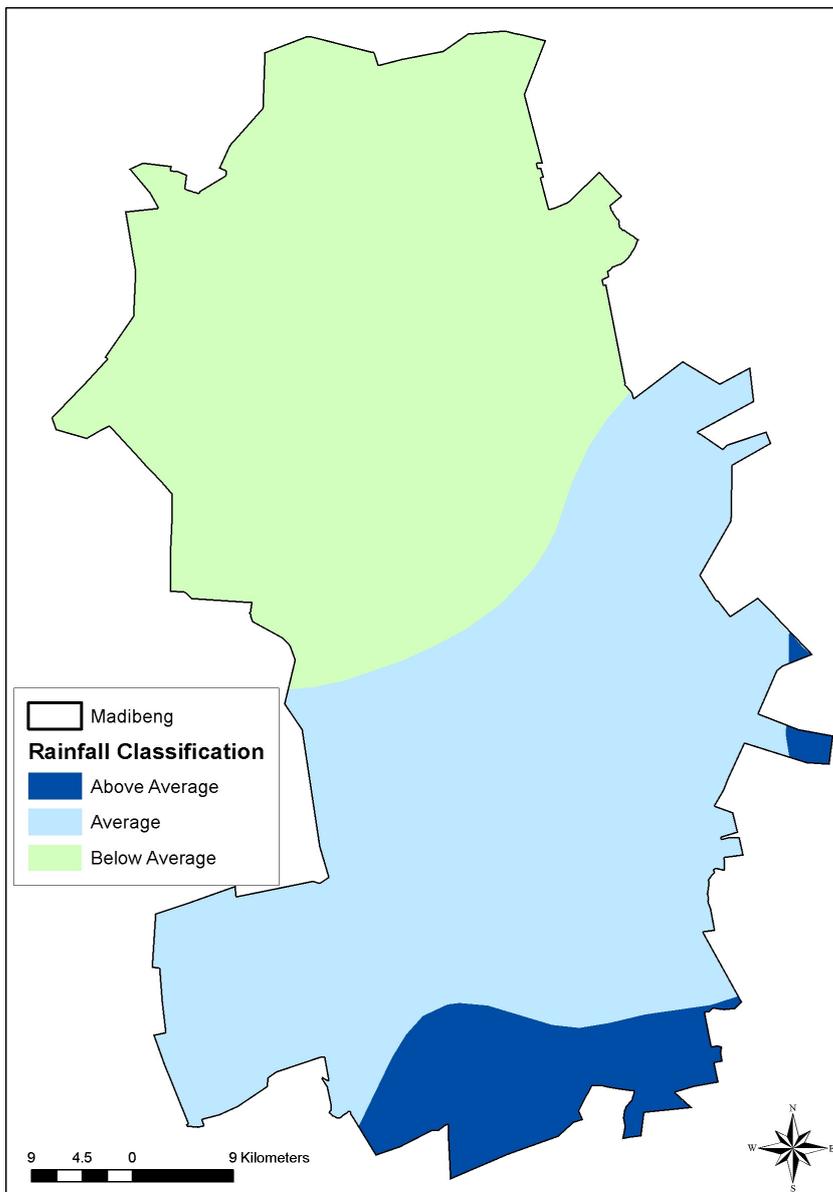


Figure 4-11: Rainfall classification for Madibeng District, 2002.

Figure 4-11 indicates that the average rainfall in Madibeng is lower in the north and increases towards the south.

- **Soil information**

The following is macro scale information with regard to soil depth and clay content. Soil depth and clay content are the two main components that determine the water holding capacity of soil.

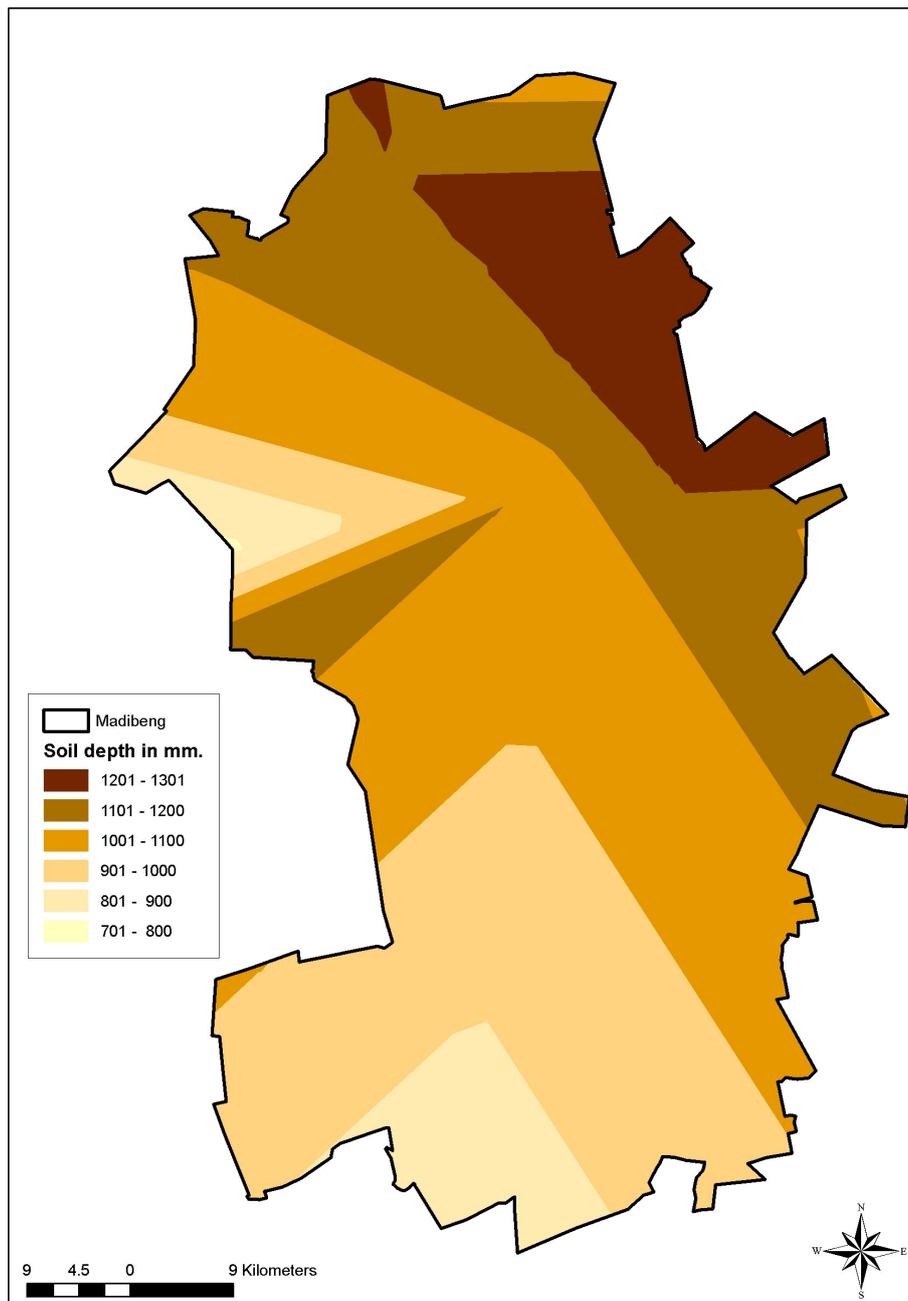


Figure 4-12: Interpolated map of soil depths for the Madibeng area

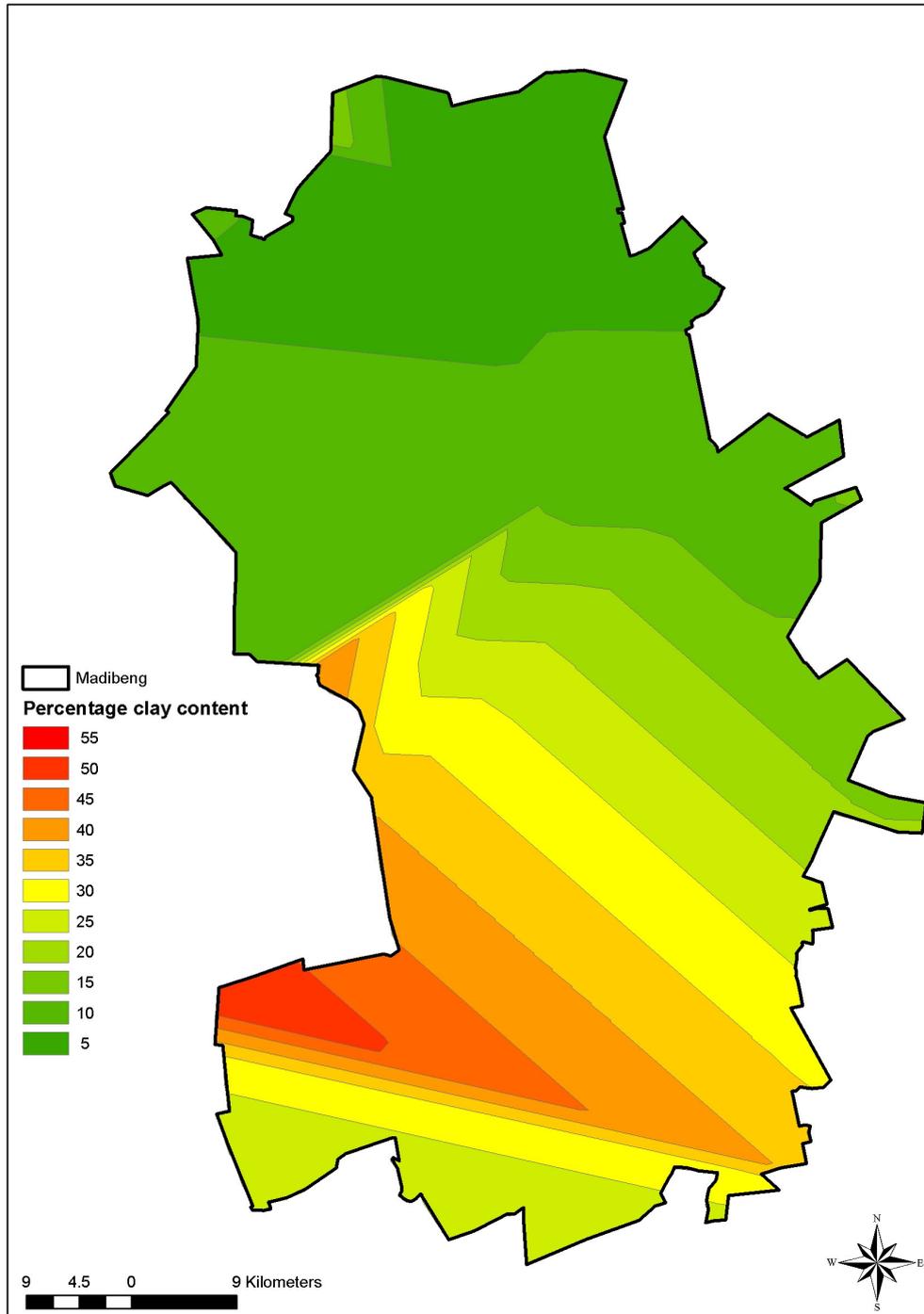


Figure 4-13: Percentage of clay content in the upper soil layers in the Madibeng area

Based on the information provided in Figures 4-12 and 4-13, it can be seen that the soils of the northern parts of Madibeng are relatively deep with a low clay content. This information was again used to classify Madibeng into areas of average, below- and above average soil potential in Figure 4-14.

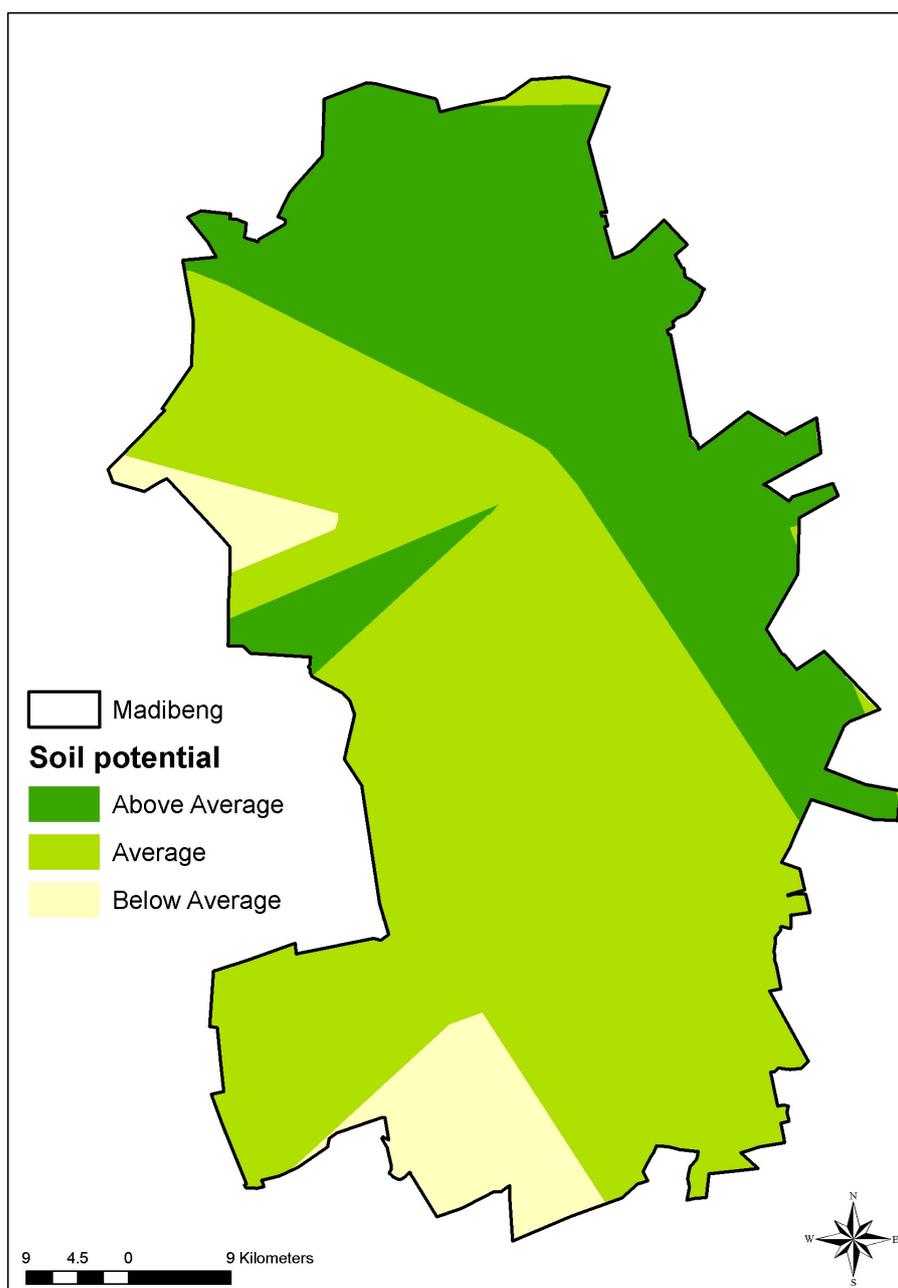


Figure 4-14: Soil potential for Madibeng Municipality

Soils to the north-east and east are deeper than those to the north-west and west. Generally the soil depth is of average depth with only small patches of below average or shallow soils in the north-west and south. The implication for a drought assessment is that soil in the area is generally of good depth for plant growth and allows for moisture penetration, and therefore holds a very low drought risk if precipitation is adequate (Van den Berg and Maley, 2002).

The drought risk assessment was then calculated using the rainfall and soil depth data for Madibeng, as is illustrated in Table 4-5.

Table 4-5: Classification criteria of the drought risk map for Madibeng District

Soil depth	Precipitation	Risk
Shallow	Below Average	High
Average	Below Average	High
Deep	Below Average	High
Shallow	Average	Medium
Average	Average	Medium
Deep	Average	Medium
Shallow	Above Average	Low
Average	Above Average	Low
Deep	Above Average	Low

The overall drought risk map based on rainfall and soil depth calculated in Table 4-5 is shown in Figure 4-15. The map shows that rainfall is a more important factor in predicting drought in the Madibeng Municipality than soil depth, as soils are of reasonable depth throughout the Municipality. The dominant affect of rainfall shows those areas with below average rainfall which, although they have above average soil depth, are most susceptible to drought incidence. These areas, comprising mainly the northern part of the district, are at high risk of drought. On the other hand, the southern area with above average rainfall but shallower soil depth is classified as a low risk area (see Figure 4-15).

These views are supported in literature by Scoones, (1996), who found that crop yields in communal areas are largely influenced by rainfall rather than soil productivity. This also applies to livestock, as fluctuations in livestock populations are correlated with rainfall variations.

According to the drought risk assessment, nearly 45 per cent of Madibeng is at high risk of drought on the basis of the soil depth and the rainfall averages. Another 45 per cent are at medium risk, while less than 10 per cent of the Municipality is classified as being at low risk of drought.

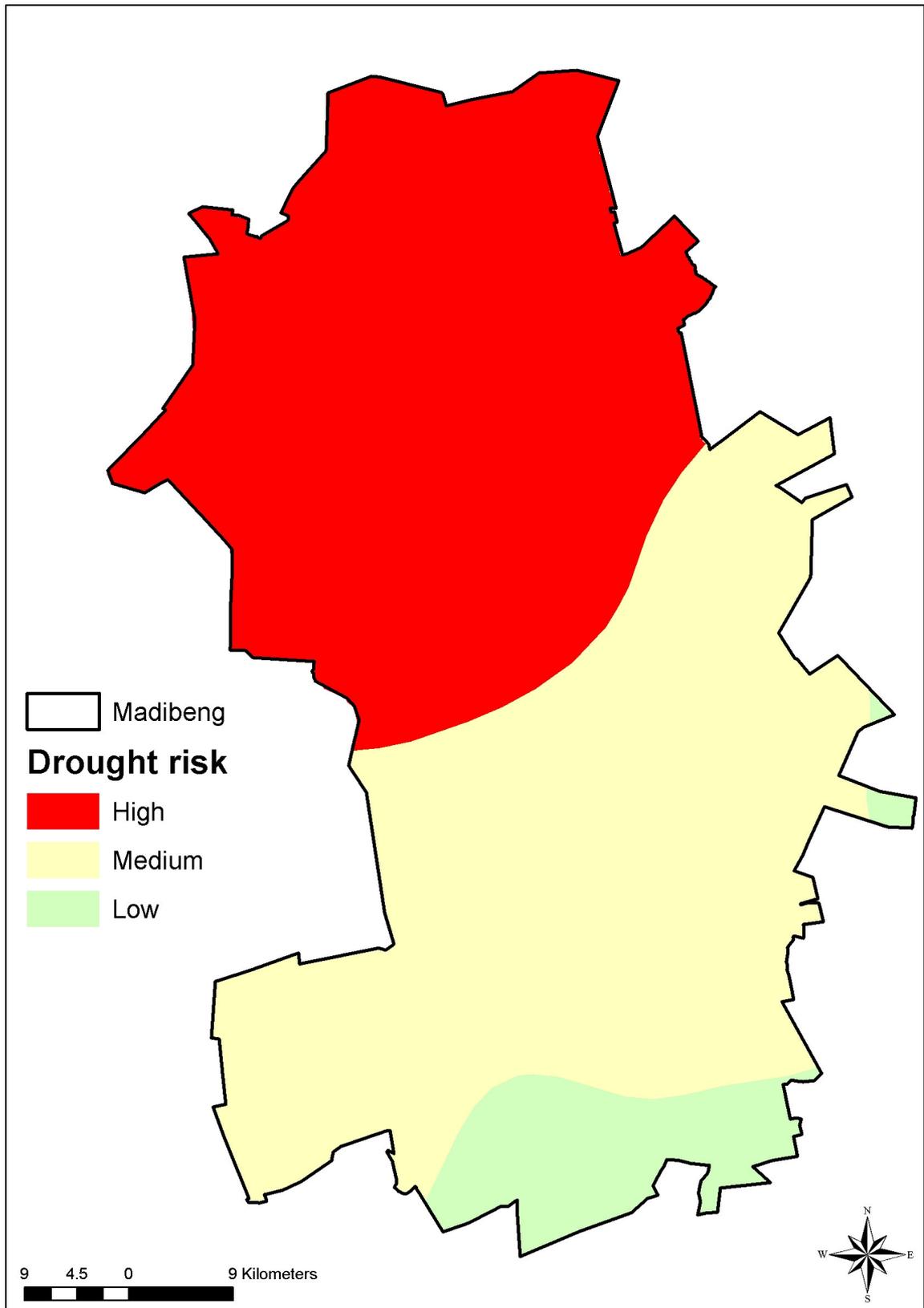


Figure 4-15: Drought risk map for Madibeng District based on rainfall and soil depth

4.3.3 Vulnerability Assessment.

Society's vulnerability to drought is determined by a wide range of factors, both physical and social, such as demographic trends, geographic characteristics and economic factors (FEMA, 1997).

The vulnerability of an area to drought depends on a host of factors that include:

- Total population and population density. The greater the population and the higher the population density, the more vulnerable the inhabitants will be to the incidence of drought.

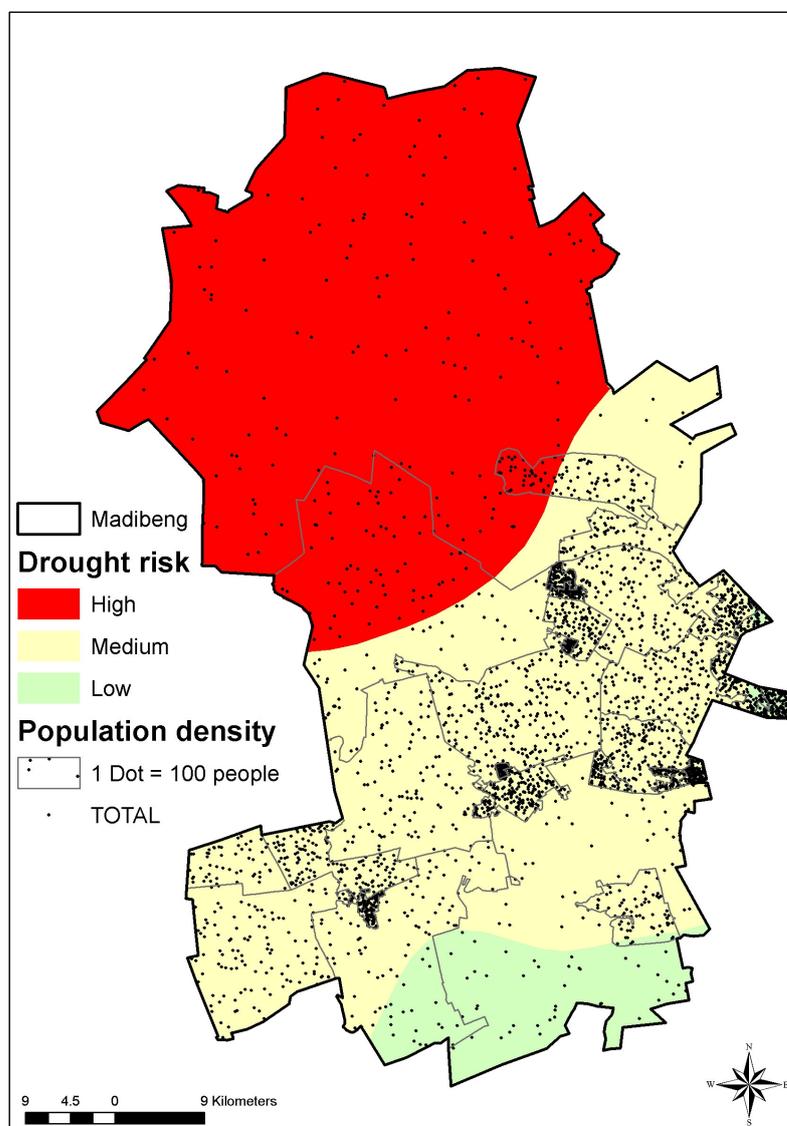


Figure 4-16: Drought risk and population density per ward in Madibeng.

Figure 4-16 indicates that the population density per ward in the high drought risk area is much lower than in the area of medium risk. This map is a good indication of the accuracy of the rainfall and drought risk map as it can clearly be seen that population density correlates with drought risk. The low density in the low drought risk area is due to the mountainous nature of the area.

- An area with a high livestock population and density is highly vulnerable to drought in terms of number of animals that might be affected by drought; the high demand for water and pasture by the animals, and the compaction of soil due to high stock density.
- An area with little or limited vegetation cover is highly vulnerable to drought as a relatively short dry spell and limited precipitation will impact negatively on the scanty vegetation and create conditions for desertification which are not easily reversible and therefore worsen the degree of vulnerability of the area to drought.

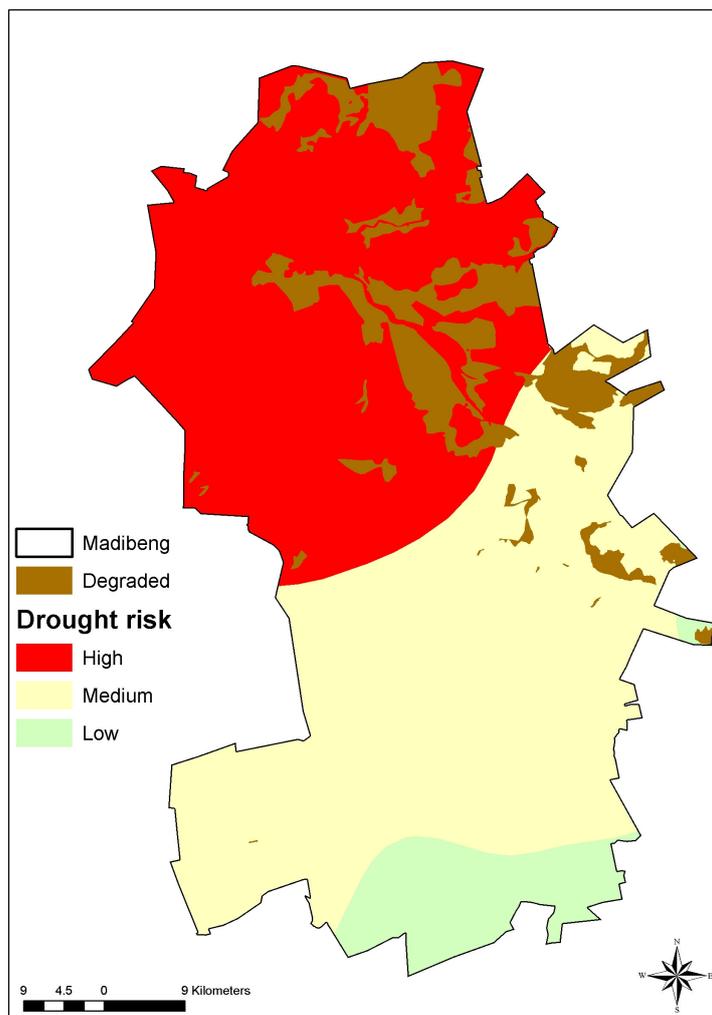


Figure 4-17: High drought vulnerability

Figure 4-17 indicates that a large percentage of the high drought risk area in Madibeng is classified as degraded land. This situation clearly increases the vulnerability of communities in the area to drought.

The incidence of forest and range fires also increases substantially during extended periods of drought, which in turn places both human and wildlife populations at higher levels of risk (FEMA, 1997).

It has to be realised that not all farmers have the same access to the necessary elements needed for successful agriculture, such as land, labour and capital assets. This is especially true for many rural households in Madibeng Municipality where a large percentage of the community practised subsistence farming on communal areas in the old regime. This also increases the vulnerability of communities in Madibeng to drought.

4.3.4 Conclusion and Recommendations.

As with the reports on floods and fire, the drought report is a very general risk assessment of Madibeng, as available data is mostly on a provincial scale and not very area specific. The results given are therefore largely generalized and should only be regarded as a general guide in assessing the drought risk and vulnerability of an area. There will definitely be exceptions to the results of this study, for instance in areas where irrigation is practised.

As was discussed earlier, the impacts of drought are far-reaching and normally on a much bigger scale than in a local municipality like Madibeng. The catchment areas of the big dams in Madibeng are also mostly outside the boundaries of the municipality, as can be seen in Figure 4-18. The implication for disaster management is that drought events outside the municipal boundary can therefore have a major impact on Madibeng.

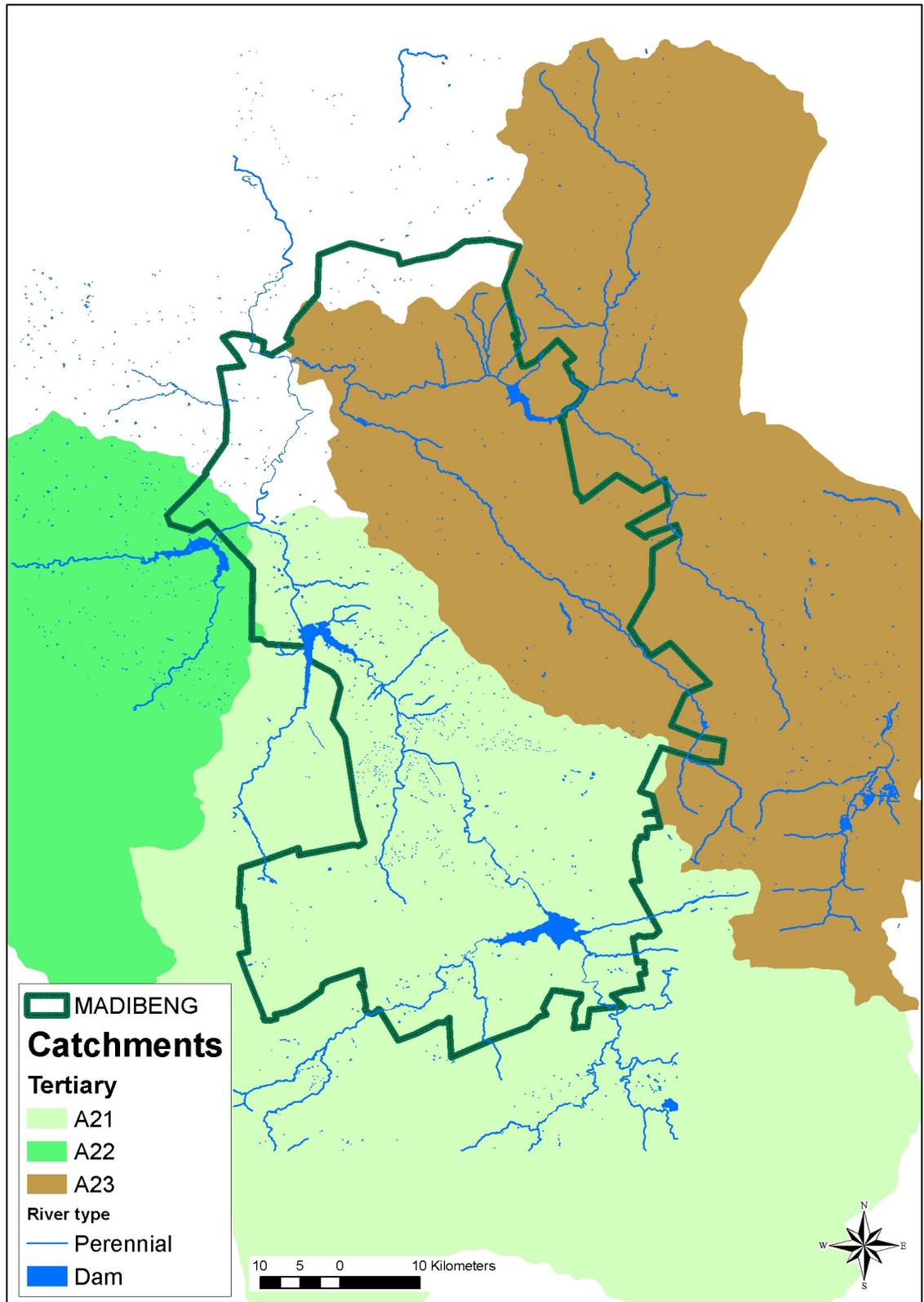


Figure 4-18: Major dam catchment areas.

Improved remote sensing from satellites and radar, as well as the use of thousands of daily in-situ precipitation measurements, have dramatically improved drought-monitoring capabilities. This data, coupled with advances made in forecasting the conditions that result in drought, could be of great value in the future in the drought mitigation process (FEMA, 1997).

Numerous early warning systems have been established in Africa to monitor a wide range of physical and social variables that signal a trend toward food insecurity. The Southern Africa Development Community (SADC), for example, monitors the crop and food situation in the region and issues alerts during periods of impending crisis.

These data sources and early warning systems are also mostly done on a regional level and are not location specific. Disaster Management will need to be supported in drought risk assessment by a Provincial or even National authorities, as the causes and effects of drought are of much bigger scale than that of the local municipality.

However, on a local level it is necessary to inform communities on the hazards of drought and also assess the level of vulnerability of the local communities to drought. Knowledge of local conditions is also important as it can be used together with regional forecasts to perform detailed drought risk and vulnerability assessments.

4.4 GEOLOGICAL HAZARDS

Geological processes can combine to produce potential natural hazards, or geohazards, that could lead to disaster if communities come into contact with such events. Landslides, sinkhole formation, active or expansive soils, erodibility, soil dispersivity, poorly consolidated soils, excavatibility, shallow water tables and inundation, are all natural geological or geomorphological occurrences that could pose a hazard to human activity. These processes should therefore be studied and, where possible, indicated to mitigate the potential hazard (Grow, 2003).

Geological hazards are mostly natural processes, but can be induced or worsened by the intervention of man. Activities such as agriculture can lead to deforestation that in turn worsens the effects of erosion and, in extreme cases, can lead to mudslides if coupled with steep slopes and heavy rain (Zschau and Küppers, 2003).

Geological hazards are worldwide a problem and there are few of these hazards that can be accurately predicted and mitigated. Not all geological hazards have the potential to cause disaster, and in Madibeng the only major potential geological hazard identified is the formation of sink-holes.

Sink-holes are a hazard in areas located on dolomite geological structures. Dolomite is known to have underground caverns that could collapse and cause sink-holes. These sink-holes are often the result of the lowering of the water table due to over-exploitation of groundwater resources. Caverns that were previously filled with water may become unstable if they are drained. The roof of the cavern may collapse, sometimes exposing a hole on the surface that is then referred to as a sink-hole (Venter, 2004).

Figure 4-19 indicates areas with dolomite geology in the Madibeng Local Municipality where sink-holes are a potential hazard. No large settlements are at risk, but there are a number of roads and the Assen mine is located in hazardous areas. As there are no communities at risk of sink holes in Madibeng, a risk and vulnerability assessment was not performed. The risk of sink-holes causing a disaster in Madibeng is therefore considered to be very low.

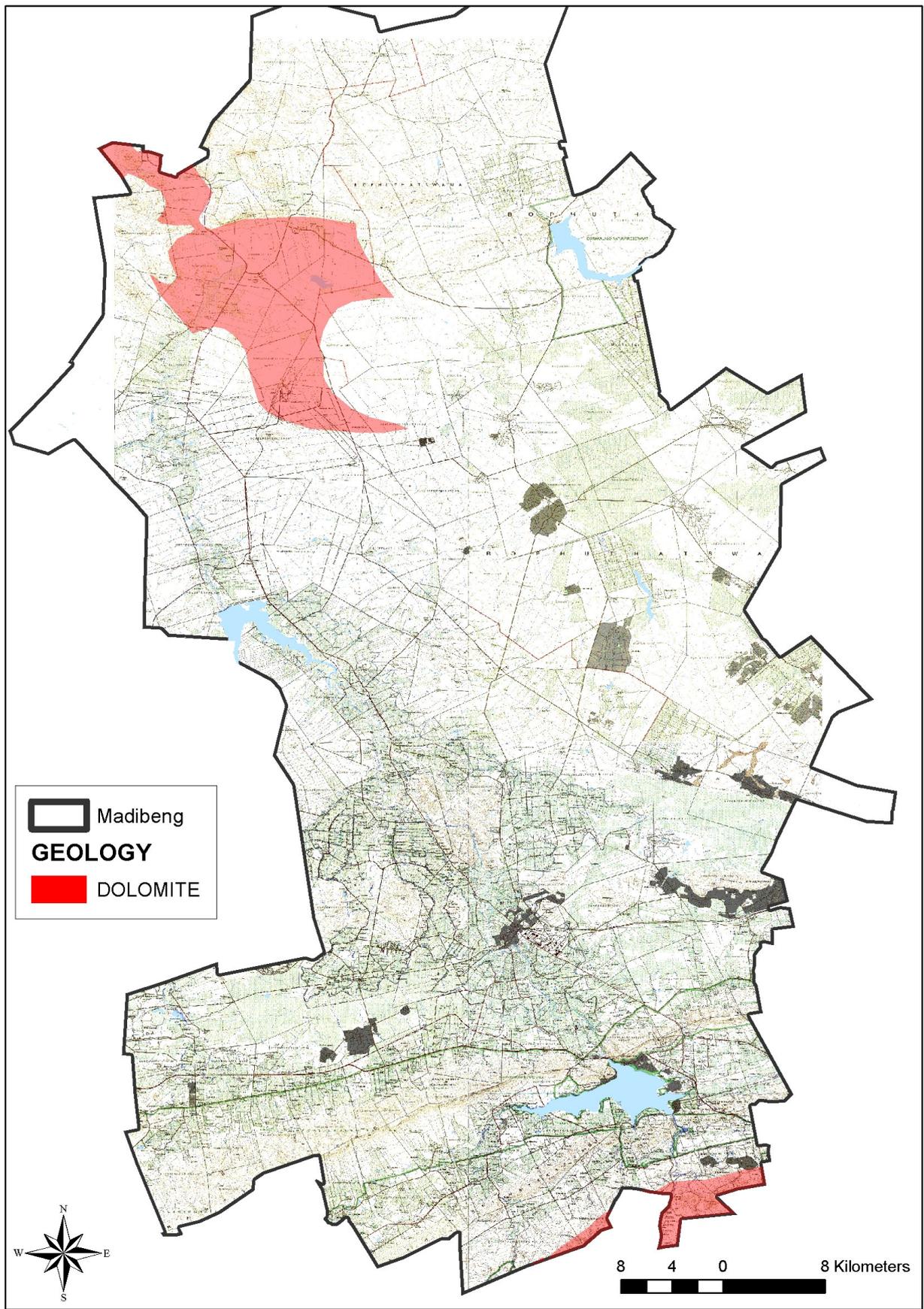


Figure 4-19: Madibeng dolomite geology

Chapter 5: HUMAN INDUCED HAZARDS

According to the United States Environmental Protection Agency, the most common hazards in any community are traffic, pollution and poverty. These are all hazards that do not exist naturally, but are caused or induced by the activities of human beings. The following chapter is an assessment of poverty levels and environmental degradation in Madibeng.

5.1 POVERTY AND ENVIRONMENTAL DEGRADATION.

The concept of sustainable development, of which disaster management is an integral part, aims at improving the quality of life for all people, without damage to the carrying capacity or productivity of the biophysical world. Poverty and the environment must therefore be addressed as interconnected issues (Rao, 2000).

Because of the general living conditions of especially the rural poor and people in informal settlements, any deterioration in the environment affects them adversely. The poor generally live in conditions that expose them fairly extensively to air and water pollution, poor hygiene and lack of sanitation. On the other hand, poverty also has an adverse effect on the environment, as poor people over-exploit the environment in an attempt to make a living off the land (Rao 2000).

Poverty can be seen as the inability of individuals, households or communities to acquire sufficient resources to satisfy a socially acceptable minimum standard of living. In its most extreme form, poverty is characterised by a lack of basic human needs, such as adequate and nutritious food, clothing, housing, clean water, and health services. Extreme poverty has a direct impact on human well-being and can be a life-threatening hazard (Corbett, 2004).

The perception that poor South Africans themselves have of poverty includes alienation from the community, food insecurity, crowded homes, the use of unsafe and inefficient forms of energy, unemployment, work that does not earn sufficient money and lacks security, and fragmentation of the family. By contrast, wealth is perceived to be

characterised by good housing, the use of gas or electricity, and ownership of major durable goods such as a television set or refrigerator (Poverty and Inequality in South Africa, 1998).

The relationship between poverty and the environment is experienced most by poor people who have very few resources and therefore utilise their environment as a resource. In doing so they may either negatively affect the environment by over-using and causing environmental degradation or, on the other hand, be negatively affected by a degraded environment.

Land degradation may be viewed as the process by which land loses some of its natural productivity as a result of overgrazing, crop production activities, deforestation, waterlogging, and a lack of conjunctive use of land and surface waters, inadequate drainage of irrigation water or combinations of these processes (Rao, 2000).

Environmental degradation and poverty are increasing phenomena in Africa, which includes some of the poorest countries in the world. Extreme environmental conditions in much of Africa aggravate the causes and effects of poverty and environmental degradation (Ben-Ari, 2002).

According to the World Development Report 2000/2001, 1.2 billion of the world's 6 billion people live on less than \$1 per day, and 2.8 billion people, or almost half of the of the world's population, live on less than \$2 per day. In 1998, at least 40 per cent of the population in South Asia and more than 46 per cent in sub-Saharan Africa were living on less than \$1 per day (World Bank, 2000).

During the late 20th century, extreme drought coupled with poverty contributed to famines in a number of African countries, including Somalia, Ethiopia, and Mali. Political instability and wars in many sub-Saharan countries have also contributed to poverty. As a result of these and other similar factors, the number of people living in extreme poverty in sub-Saharan Africa grew from 217 million in 1987 to more than 300 million in 1998 (Wilhite, 1998).

In per capita terms, South Africa is seen as an upper-middle-income country, but despite this relative wealth, many South African households live in poverty or are of continuing vulnerability to becoming poor. The distribution of income and wealth in South Africa is also among the most unequal in the world, and many households still have unsatisfactory access to education, health care, energy and clean water (Poverty and Inequality in South Africa, 1998).

5.1.1 Causes of Poverty

The reasons for poverty are not clear and can have complicated and multi faceted explanations. Some experts suggest that the world is overpopulated, has too few employment opportunities and not enough resources. But this would be simplifying the most serious hazard, as the reasons for poverty could be environmental, political, social, and economic, or more likely a combination of these elements. In most cases, the causes and effects of poverty interact, so that what makes people poor also creates conditions that keep them poor (O'Connor, 1991).

Primary factors that may lead to poverty include:

- overpopulation;
- the unequal distribution of resources in the world economy;
- inability to meet high standards of living and costs of living;
- inadequate education and employment opportunities;
- environmental degradation and Natural Disasters;
- economic and demographic trends (Corbett, 2004).

5.1.1.1 Overpopulation.

Overpopulation is a scenario in which there are large numbers of people living in a geographic area with inadequate resources to ensure the well-being of all the people in that area. It can result from high population density or from low resource availability, or from both. Excessively high population densities put stress on available resources. Only a certain number of people can be supported on a given area of land, and that number depends on how much food and other resources the land can provide (Miller, 1999).

Traditional land use practices that were effective in the past might not be viable anymore as population density has increased and resources are dwindling. In countries where people live primarily by means of simple farming, gardening, herding, hunting, and gathering, large areas of land support only small numbers of people because these labour-intensive subsistence activities are relatively unproductive in First World terms. In many developing countries high birth rates still contribute to overpopulation. Many poor communities believe that children are an asset that will provide labour, especially in areas where labour-intensive subsistence farming is practised. Many traditionally rural societies in Africa encourage large families, as many children can provide labour and later care for their parents, thus providing a form of security (O'Connor, 1991).

In some of the poorer countries there is also the problem that governments do not have the capability to provide formal family planning programs and or birth control measures. This causes a situation in which even though people do not want to have many children, it is difficult for them to control the number of children they actually have (Alcock, 1993).

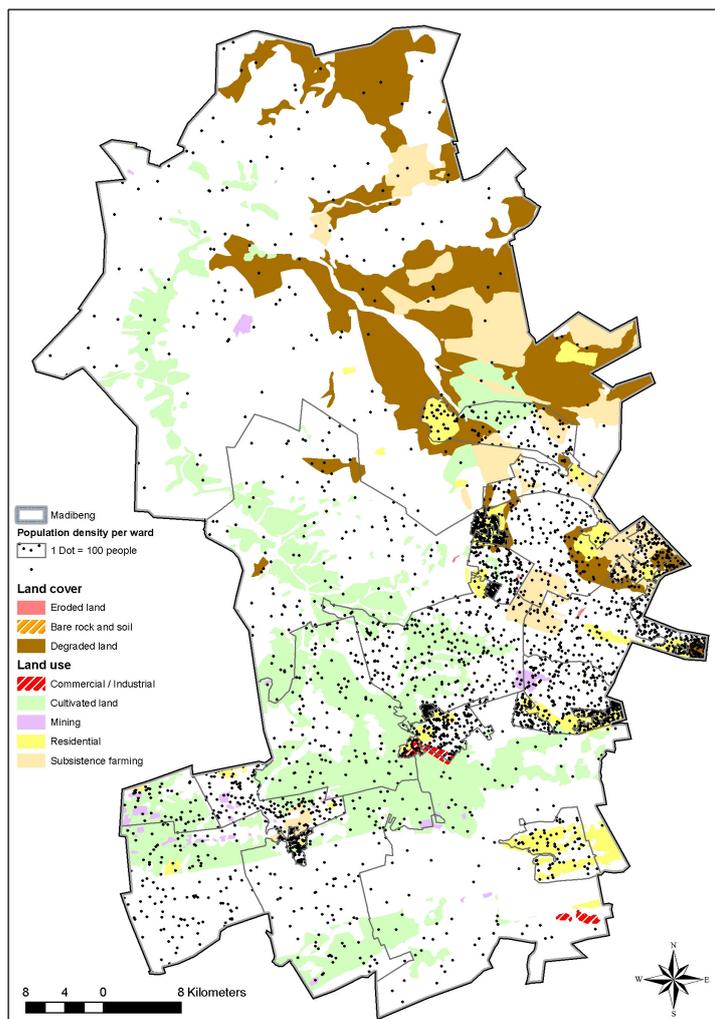


Figure 5-1: Madibeng population density per ward.

As can be seen in Figure 5-1, the wards in the eastern part of Madibeng are populated more densely than those in the northern area. The explanation for this is that these densely populated areas were part of the former Homelands and many people were forced to live there in the past. The relatively lower population density in the northern areas could be the result of the widespread environmental degradation present in the area, as indicated in dark brown. The damaged environment is therefore not able to support the same number of people as in other areas. These areas are also more drought prone and therefore less suitable for agriculture.

5.1.1.2 Unequal Distribution of Resources

The unequal distribution of wealth and resources in Africa generated in the colonial period has become even more pronounced in the post-industrial or information age. Members of societies with access to good educational opportunities and advanced technology profit far more from the emerging global economy than do members of less developed societies. On a National scale in South Africa the Apartheid Regime can also be blamed for the uneven distribution of wealth and resources (Mortimore, 1998).

Widespread poverty, which often leads to epidemics, starvation, and death, are much more common in developing countries. In the past few decades, millions of people have starved and died as a result of famine in such countries as Bangladesh, Ethiopia, North Korea, Somalia and Sudan. As recently as 1998, almost one person in four (23 per cent) residing in developing countries lived on less than \$1 a day (Throssel, 2002).

Developing countries also often lack the infrastructure provided, for example, by transportation systems and power-generating facilities. These basic resources are necessary for the development of industry, and without industries developing countries have to rely on trade with developed countries for manufactured goods, that come at unaffordable prices for the poor people of such countries (Ben-Ari, 2002).

5.1.1.3 High Standards of Living and Costs of Living

People in some developing countries may consider having productive gardens, some livestock, and a house of thatch or mud-brick, as being well-off. In rural areas, communities may be used to living conditions without access to plumbing, electricity or formal health care. By the standards of developed countries, such living conditions are considered to be signs of poverty (Bhalla and Lapeyre, 1999).

Developed countries tend to have very high costs of living. Even the most basic lifestyle in these countries, with few or no luxuries, can be relatively expensive. In South Africa there is a somewhat unique situation that, in areas like Madibeng, First and Third World conditions may exist in the same region. In areas like these, the poor in the First World areas might be considered as being rich by the poor in the Third World areas (Corbett, 2004).

Especially in areas like these, even people with employment that achieve the legal minimum wage may not be able to cover their basic expenses and bridge the poverty gap from Third to First World conditions.

5.1.1.4 Inadequate Education and Employment Opportunities

There is a very strong correlation between level of education and standard of living. The poverty rate among people in South Africa with no education is sixty nine percent, compared with fifty four percent among people with primary education, twenty four percent among those with secondary education, and three percent among those with tertiary education (Poverty and Inequality in South Africa, 1998).

Illiteracy and lack of education are common in poor countries. Governments of developing countries often do not have the money and resources to provide for good public schools and qualified teachers, especially in rural areas. Whereas virtually all children in industrialized countries have access to an education, only about 60 per cent of children in sub-Saharan Africa even attend elementary school. Without education, most people have difficulty in finding income-generating work (Gama, 2002).

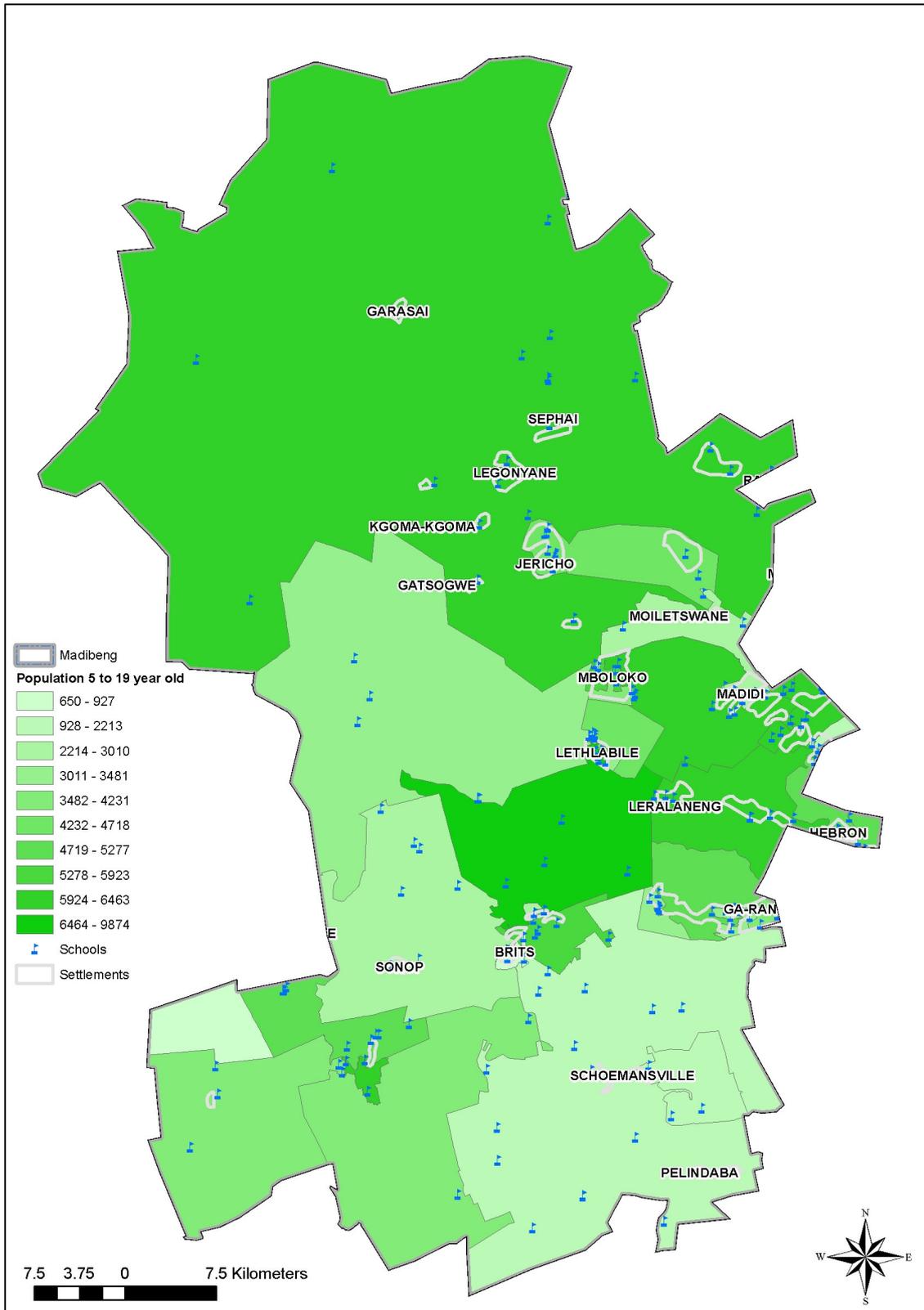


Figure 5-2: Population 5-19 year olds per ward and spatial distribution of schools in Madibeng.

Figure 5-2 indicates the number of potential school pupils per ward in Madibeng according to the 2001 census data. The assumption was made that all children from the age of 5 to 19 attend schools. The map also shows the spatial distribution of schools in the Municipality, as received from the Demarcation Board. Schools in Madibeng seem to be well distributed, with larger concentrations around settlements, as should be expected. According to the available information only the community at Marikana does not have a school.

The presence of schools is not an accurate measure of the quality of schooling available to the community of Madibeng. To perform a more accurate assessment of the educational opportunities in Madibeng more detailed data is needed on educational facilities, such as the numbers of students per teacher, resources such as the availability of learning material and qualifications of teachers.

Without a good schooling, people find it hard to get employment that can provide a good income. A lack of education then increases unemployment and unemployed people do not make any money; therefore, high unemployment leads to high levels of poverty. However, unemployment figures indicate only the number of people who have no work and are seeking employment. Such figures are not necessarily an accurate indicator of the number of people living in poverty. There are also the working poor, who earn wages that are too low to support their households (Ileffe, 1987).

Poverty and unemployment levels are closely correlated: 55% of people from poor households are unemployed, compared with 14% of those from better off households. Poor households are characterised by a lack of wage income, either as a result of unemployment or of low-paying work due to lack of education, and typically rely on multiple sources of income, which help reduce risk (O'Connor, 1991).

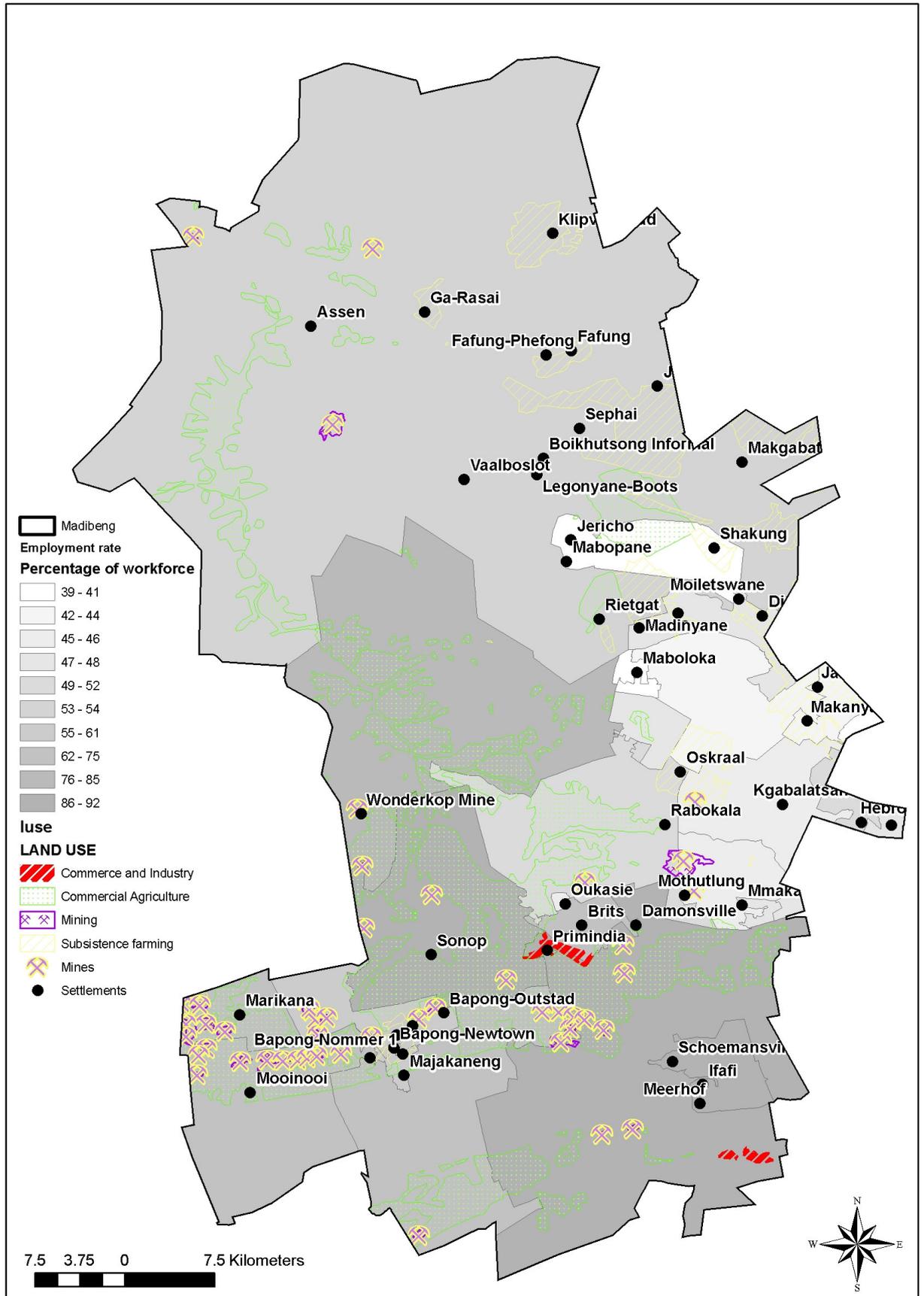


Figure 5-3: Madibeng employment rate and employment opportunities.

Figure 5-3 indicates the employment levels in Madibeng given as a percentage of employed people relative to the potential workforce (total employed and unemployed people) per ward. The map is also an attempt to assess the spatial relationship between employment opportunities and actual employment levels. From this map it is clear that employment levels are higher in the wards where there are higher concentrations of mining activities and commercial agriculture.

5.1.1.5 Environmental Degradation and Natural Disasters

In South Africa the poor often live in fragile environments that are susceptible to degradation. The old land policies and the creation of the homelands caused landlessness, overpopulation, overgrazing and the resulting environmental degradation (Walmsley, 2002).

Environmental degradation may result from a variety of factors, including overpopulation and the resulting overuse of land and other resources. Intensive farming, for instance, depletes soil fertility, thus decreasing crop yields. Pollution is also a well known cause of environmental degradation. Sources of pollution include mines, power generating facilities (especially those burning fossil fuels), industry and agriculture (Miller, 1999).

In many parts of the world, environmental degradation is an important cause of poverty. Environmental problems have led to shortages of food, clean water, materials for shelter, and other essential resources. As natural resources are degraded, people who live directly off their environment suffer most from the effects.

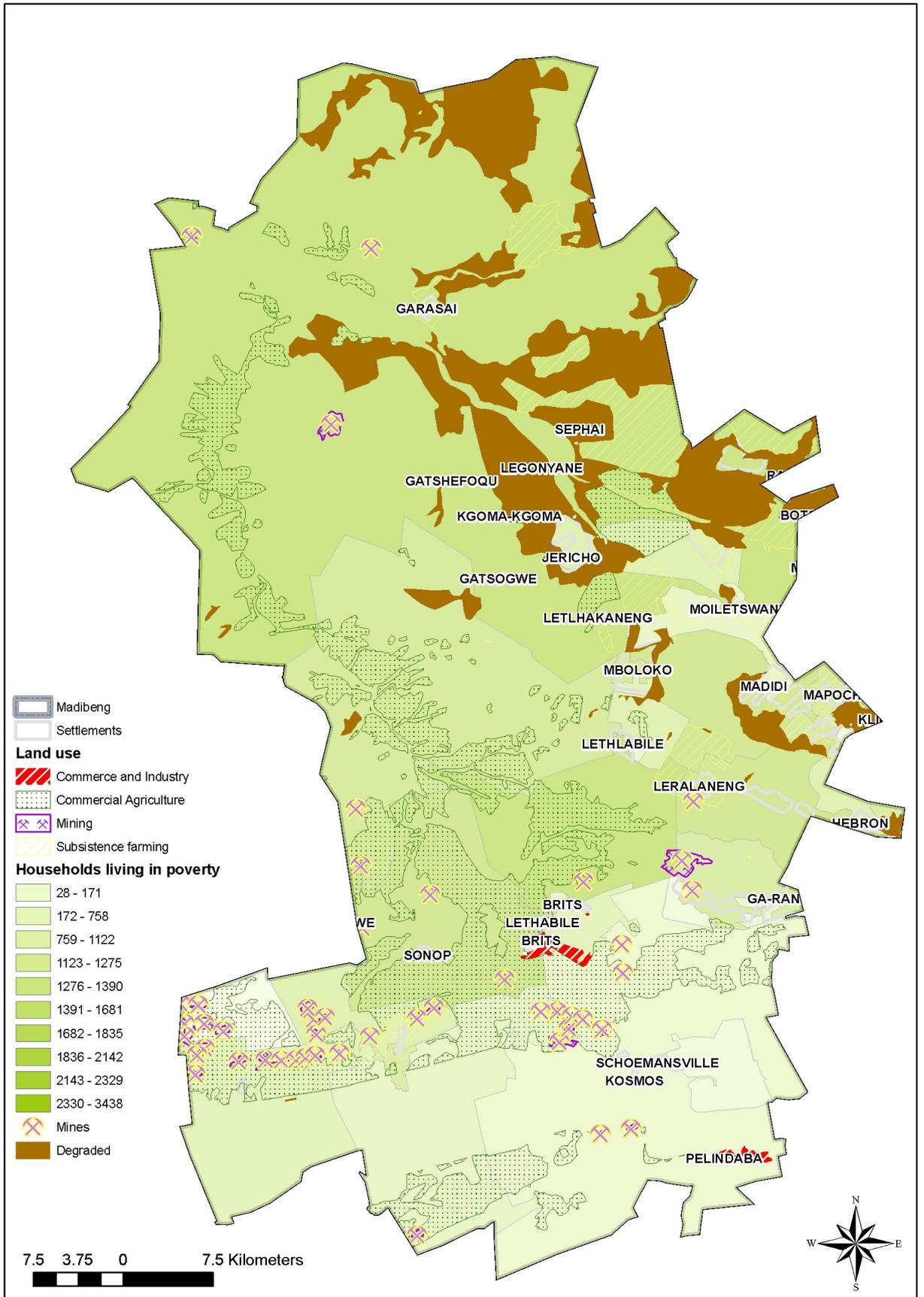


Figure 5-4: Poor households and environmental degradation.

Large areas in the Northern region of Madibeng have been classified as being degraded (Figure 5-4). These are also the areas with the highest number of households living off less than R800 per month (According to 2001 Census data). The high poverty level in the area could be attributed to a lack of employment opportunities as well as a degraded environment.

On the other hand, it could be argued that degradation of the environment in this area is due to the large number of poor households overusing the available resources. The important issue is that the cycle of poverty and environmental degradation is clearly identifiable in the northern part of Madibeng and should be high priority for decision makers.

In many poor countries development is repeatedly interrupted by natural disasters such as floods, drought and earthquakes. Natural disasters seem to be more common and on the increase in the developing world. In the last decade 94 percent of the 568 major natural disasters in the world, and 97 percent of the related fatalities, occurred in the developing world. The frequency of disaster events also seems to be on the increase, probably as result of increasing population density and possibly changing weather patterns (Miller, 1999).

Natural disasters can lead to increases in poverty and can retard human development. It is also the poor that are normally worst affected, decreasing their chances further of escaping from the clutches of poverty (World Bank, 2000).

5.1.1.6 Economic and Demographic Trends

Some researchers also blame economic and demographic shifts (changes in the make-up of populations) as elements that can increase or negatively impact on poverty. The phenomenon of male-migration is very common among the rural communities in Africa. In many areas males migrate to other areas in search of employment, especially during times of drought. During the Apartheid era migratory work was very common in South Africa. This type of migration can lead to a variety of social problems and contributes to the number of female-headed households (that tend to be more vulnerable to poverty) in many areas (O'Connor, 1991).

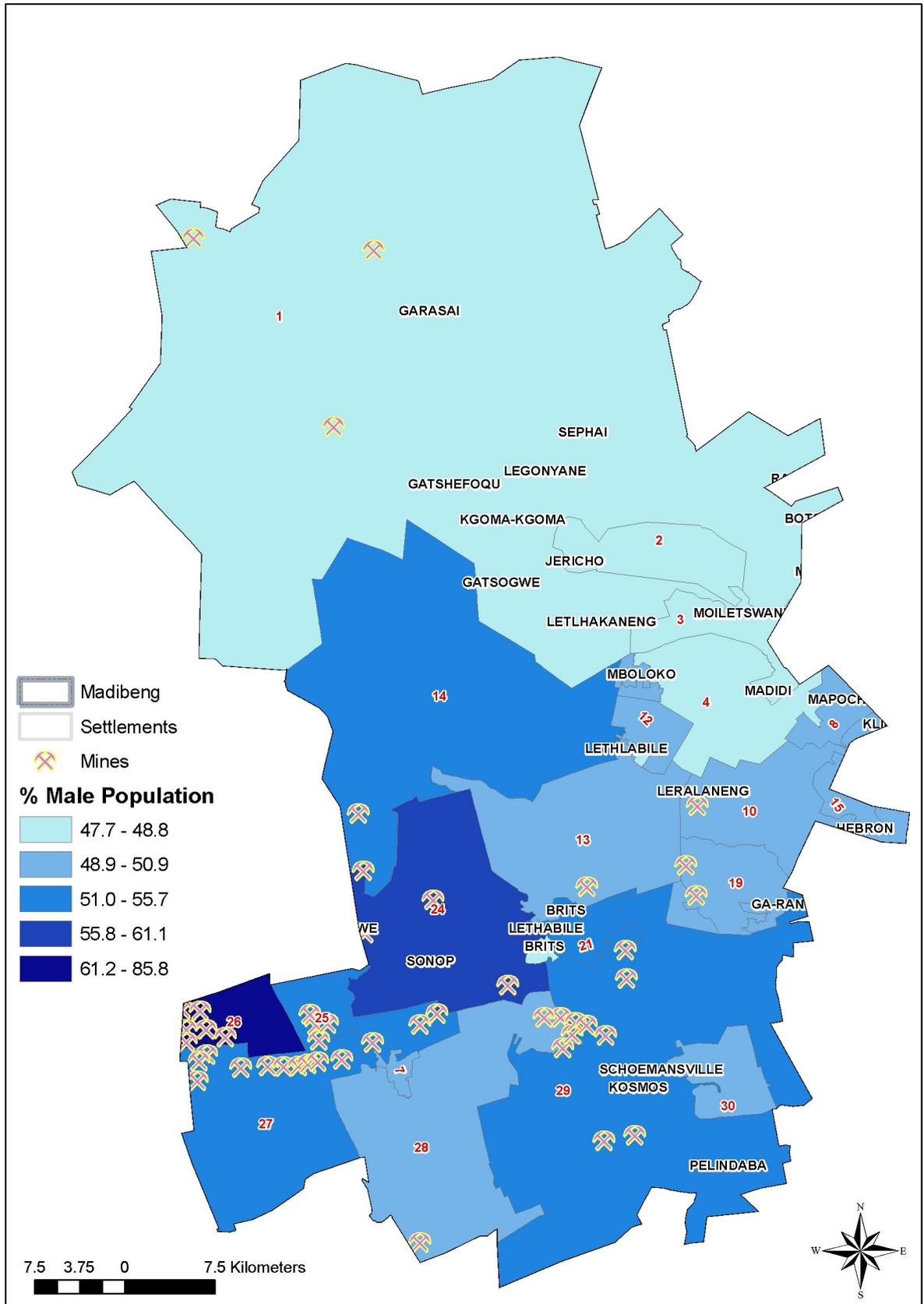


Figure 5-5: Percentage male population per ward.

Figure 5-5 indicates the percentage male population per ward in Madibeng. Although most of the municipality has a fairly equal distribution of males and females, ward number 26 has a male population of 4368 out of a total population of 5089. The obvious reason why ward number 26's population is nearly eighty six percent male is the large concentration of mines in the area. During interviews with representatives of Madibeng it was also mentioned that there are large numbers of mainly male immigrants especially from Mozambique working on the mines in Madibeng.

The impact that the HIV/AIDS epidemic will have on poverty in South Africa is still uncertain, but it could have a marked effect on the demography of the country. The looming HIV/AIDS disaster will have a definitive impact on the economy, as the effect of AIDS is largely concentrated in the younger demographic classes that are the most economically active. Unfortunately no specific information on the prevalence or distribution of HIV/AIDS could be found for Madibeng, to be compared to poverty levels, in order to perform a risk assessment.

5.1.2 Effects of Poverty

Poverty has wide-ranging and often devastating effects. Many of the hazards associated with poverty, such as poor nutrition and health problems, result directly from having too little income or too few resources. As a result of poor nutrition and health problems, infant mortality rates among the poor are higher than average, and life expectancies are lower than average.

Specific hazards caused by poverty may include infectious disease, mental illness and drug- and alcohol dependence. Other hazards linked to poverty are more complicated and difficult to explain. For example, studies link poverty to crime, but it cannot be said that all poor people have criminal tendencies. In many cases, the primary effects of poverty lead to other problems. Malnutrition, for example, lessens the body's resistance to illness, leading to health problems (Corbett, 2004).

5.1.2.1 Malnutrition and Starvation

Famines have been a common occurrence throughout Africa and in the past could normally be blamed on extreme drought conditions. Although famine still remains a hazard in Africa, it is a scenario that is on the decrease due to better governance, planning and foreign aid programmes. Instead, the risk of famine has largely been replaced by malnutrition (Ileffe, 1987).

Hunger, malnutrition and starvation are some of the most common effects of poverty in developing countries. Poverty can lead to a situation in which people cannot afford the quantity or quality of food that is needed by a human to sustain a healthy body and mind. Extreme cases of hunger can lead to starvation, but malnutrition is the everyday reality that affects most poor communities, even in Madibeng (Garcia and Escudero, 1982; Colgon, 2002).

The malnutrition caused by a lack of nutritious food, could lead to death in extreme cases, or to underdevelopment, both physically and mentally. This in turn leads to educational failure and low paid work and more poverty. Children are most at risk. Hunger is also a seasonal occurrence for many of the rural people of Africa that rely on the rainy season to cultivate their crops (Harrison, 1993; O'Connor, 1991).

Poor children in developing countries are generally most at risk, commonly from a deficiency known as protein-energy malnutrition. In these cases, children lack protein in their diets, especially as a result of an insufficient amount of mother's milk. Protein-energy malnutrition leads to a variety of problems, including gastro-intestinal disorders, stunted growth, poor mental development and high rates of infection (De Rose *et al.*, 1998).

In addition to calorific malnutrition, most poor children and adults suffer from severe vitamin and mineral deficiencies, also described as micronutrient deficiencies. These deficiencies can lead to mental disorders; damage to vital organs and failure of the senses, such as poor vision and problems conceiving or delivering babies (Harrison, 1993; De Rose *et al.*, 1998).

Where malnutrition does not cause death, it impacts on the quality of life and opportunities of those affected, and on their ability to earn adequate income. While the risk of death increases with the severity of malnutrition, the largest numbers of deaths occur among those affected by mild to moderate malnutrition. Micronutrient malnutrition is a public health problem of considerable significance in South Africa.

Hunger also has economic impacts, as a hungry person is less productive. The amounts of calories a person consumes will determine the amount of physical work the person is able to do. A person that does not eat enough will be less productive, earn less and exacerbate poverty (O'Connor, 1991).

A simple example is taken from the Second World War, where the German Military found they could boost coal production from the Ruhr pits simply by giving the miners more food. When the daily allowance was raised from 2800 calories to 3500, daily output per man rose from seven tons to nine and a half tons (Harrison, 1993).

5.1.2.2 Infectious Disease and Exposure to the Elements

In addition to the effects of malnutrition, the poor experience high rates of infectious disease. Malnutrition lowers the body's resistance to illness and illness aggravates malnutrition. Inadequate shelter or housing also creates conditions that promote disease. Without decent protection, many of the poor are exposed to severe and dangerous weather as well as to bacteria and viruses carried by other people and animals (Colgan, 2002).

The pattern of disease differs dramatically between First and Third World countries. The major killers in the First World are cancer (15%) and circulatory diseases (32%), whereas in the Third World cancer accounts for (4%) and circulatory diseases (15%). The big killers in the poor countries are infectious, parasitic and respiratory diseases, often worsened by the effects of malnutrition and the HIV/Aids epidemic. These diseases cause forty four percent of deaths in the Third World compared to eleven percent in the First World (Harrison, 1993; Colgan, 2002).

In arid regions, drought can leave the poor without clean water for drinking or bathing. Inadequate sanitation almost always accompanies inadequate shelter. Because the poor in developing nations commonly have no running water or sewage facilities, human excrement and garbage accumulate and quickly become a breeding ground for disease.

The poor are also often uneducated about the spread of diseases, notably sexually transmitted infections (STI's). As a result STI rates are high among the poor. In particular, the incidence of acquired immunodeficiency syndrome (AIDS) among poor people is higher than average. Based on figures by CARE USA, by the end of 2001, an estimated 40 million people were infected with HIV, with over 95 per cent of those living in developing countries. Approximately 18.5 million people with HIV are women and 3 million are children under age 15.

The transmission of HIV/AIDS seems to be accelerated by the combination of poverty, natural disasters, violence, social chaos and the disempowered status of women. The profile of HIV infected people is a picture of poverty, and there is a definite increase of HIV cases among low income and less educated people (World Bank, 2000).

The illness also increases the risk of a household or an individual becoming impoverished, and lowers the general level of health in communities because of its close relationship with other communicable and poverty-related diseases such as tuberculosis (Colgan, 2002).

Like malnutrition, disease also has major economic implications through the costs of caring for the ill, ill people not being able to go to work, and the loss of breadwinners in many families. Especially in the African social setup a family's well-being is strongly linked with the physical health of its members. When a family-member becomes ill or disabled, the entire family faces an economic as well as a physical burden.

5.1.2.3 Crime and Violence

Anger, desperation, and the need of money for food, shelter, and other necessities may all contribute to criminal behaviour among the poor (Throssel, 2002).

In South Africa the wealthy tend to be victims of property crime, while poor people are more at risk of personal crime. Africans are 20 times more likely to be the victim of a homicide death than whites, while in 1995, 95% of reported rapes were of African women. Poverty, high unemployment and marginalisation of men increase the risk of violence against women, and poorer women are often trapped in abusive relationships due to dependence on partners for food, shelter and money (Corbett, 2004).

Areas inhabited by the poor are also less likely to have infrastructure such as street lighting and telephones, public transport and decent roads that facilitate crime prevention. Structures occupied by the poor are also generally less secure than those of wealthier people. Poor people are also unlikely to be able to supplement the services of the police by purchasing private security (Corbett, 2004).

5.1.3 Risk Assessment

The most commonly used method of measuring poverty is based on income or consumption levels. A person is considered poor if his or her consumption or income level falls below some minimum level necessary to meet basic needs. This minimum level is usually called the "poverty line". The quantity that is necessary to satisfy basic needs varies across time and geographical areas. Therefore, poverty lines vary in time and place, and each country uses criteria which are appropriate to its level of development, societal norms and values (World Bank, 2000).

Information on consumption and income for Madibeng was obtained from the 1996 census survey, during which households were asked to answer detailed questions on their sources of income, employment and living conditions. This information for Madibeng was then applied to execute a risk assessment. The available information for Madibeng made it possible to follow two approaches in assessing a community's risk of poverty in the Municipality:

- The first is an income level approach based on the spatial distribution of income levels in Madibeng and the distribution of households living in poverty.
- Secondly, a basic needs approach was followed, where communities' abilities to access resources such as clinics, education, electricity, water and roads were assessed.

5.1.3.1 Income level approach

Income poverty occurs when the income level of an individual falls below a nationally defined poverty line. This implies that the income of the individual is not sufficient to provide for basic minimum needs, especially food. The UNDP facilitates comparative assessments of countries' progress in poverty reduction. For example, the World Bank has established an international poverty line at \$1 per day per person for the purpose of international comparison.

For the purpose of this study, the representatives of Madibeng Municipality agreed that all households with an income of less than R800 per month should be regarded as poor. The following map indicates the number of households per ward that are living on less than R800 per month.

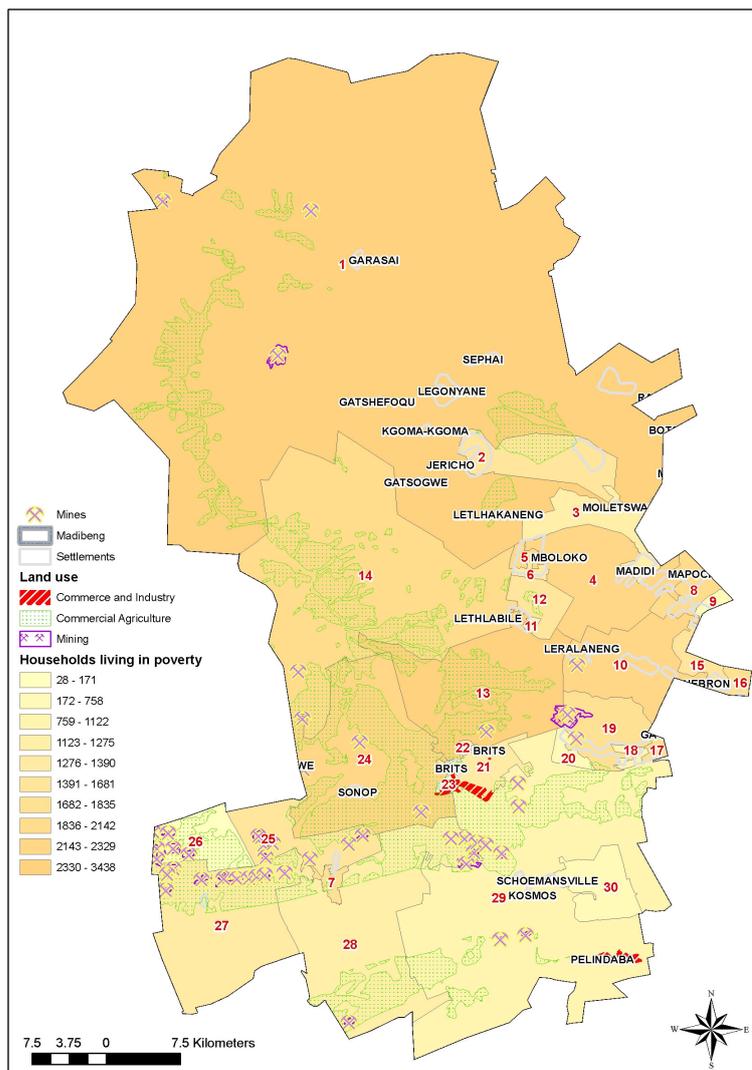


Figure 5-6: Number of households per ward in Madibeng living in poverty.

Figure 5-6 indicates that the greatest number of poor households live in the Northern wards of Madibeng. The lowest number of poor households were found in the areas around Brits, Hartbeespoort and Marikana that are located in the Southern parts of the Municipality. The Map also shows the spatial distribution of mining, industry and commercial agricultural activities that are the main sources of employment in Madibeng. It is clear that the areas with more employment opportunities have fewer numbers of poor households.

5.1.3.2 Basic needs approach.

Income alone cannot provide the basis for a poverty assessment, especially in areas such as Madibeng where there are communities that make a living out of subsistence farming. The well-being of these communities is more closely associated with their environment and would, for example, be closely linked to the availability of safe drinking water (World Bank, 2000).

Infrastructural services such as communications, power, transportation, provision of water and sanitation, are very important to the activities of the household and a nation's economic production. In order to ensure that growth is consistent with poverty alleviation, infrastructural development needs to be extended to all sectors of the population. Access to at least minimum infrastructure services is one of the essential criteria for defining welfare and mediating poverty (Corbett, 2004).

Different infrastructural elements have different effects on improving quality of life and reducing poverty. For instance, access to reliable energy, clean water and sanitation helps reduce mortality and environmental degradation and saves time for productive tasks; while transport enhances access to goods, services and employment, and communications allows access to services and information on economic activities.

- **Running water and sanitation**

Historically the rise and fall of civilizations and their economic prosperity has been strongly linked with access to water and its utilization. Ancient civilizations flourished along the great rivers, including the Nile, Indus and Yangtze, but, on the other hand, several areas have lost their economic potential due to unsustainable use of water

resources. The quality and quantity of drinking water and sanitation is therefore extremely important to the welfare of any community (Rao, 2000).

A Dutch adviser to UN Secretary-General Kofi Annan said: “The world is in a water crisis, with the problem perhaps most acute in Africa”. Globally, more than one billion people do not have access to safe drinking water, and half of the world's population lacks adequate sanitation. More than 2 million people die annually from water-related diseases (Kirby, 2002).

Access to clean water is a vital public health necessity and a basic human right. People need water to grow food and for personal use. Agriculture in Africa accounts for about thirty five percent of the continent’s gross national product, forty percent of its exports and seventy percent of its employment. In view of this it is obvious that water is the resource with the greatest single impact upon economic development, while safe drinking water and proper sanitation is essential for the improvement of public health. Safe drinking water and proper sanitation can reduce the morbidity and mortality rates of some of the most serious water-related diseases by up to eighty percent (Kirby, 2002).

As mentioned before, the absence of clean drinking water and proper sanitation services increases people’s vulnerability to poor health, which reduces their quality of life and productive capacity, and burdens health care and social welfare services (Colgan, 2002).

Provision of dependable water supplies can therefore have a strong positive effect on food security and income generation, especially for the rural poor. Substantial livelihood gains are likely to be made by providing water for small farming and other enterprises, as people spend less valuable labour time obtaining water.

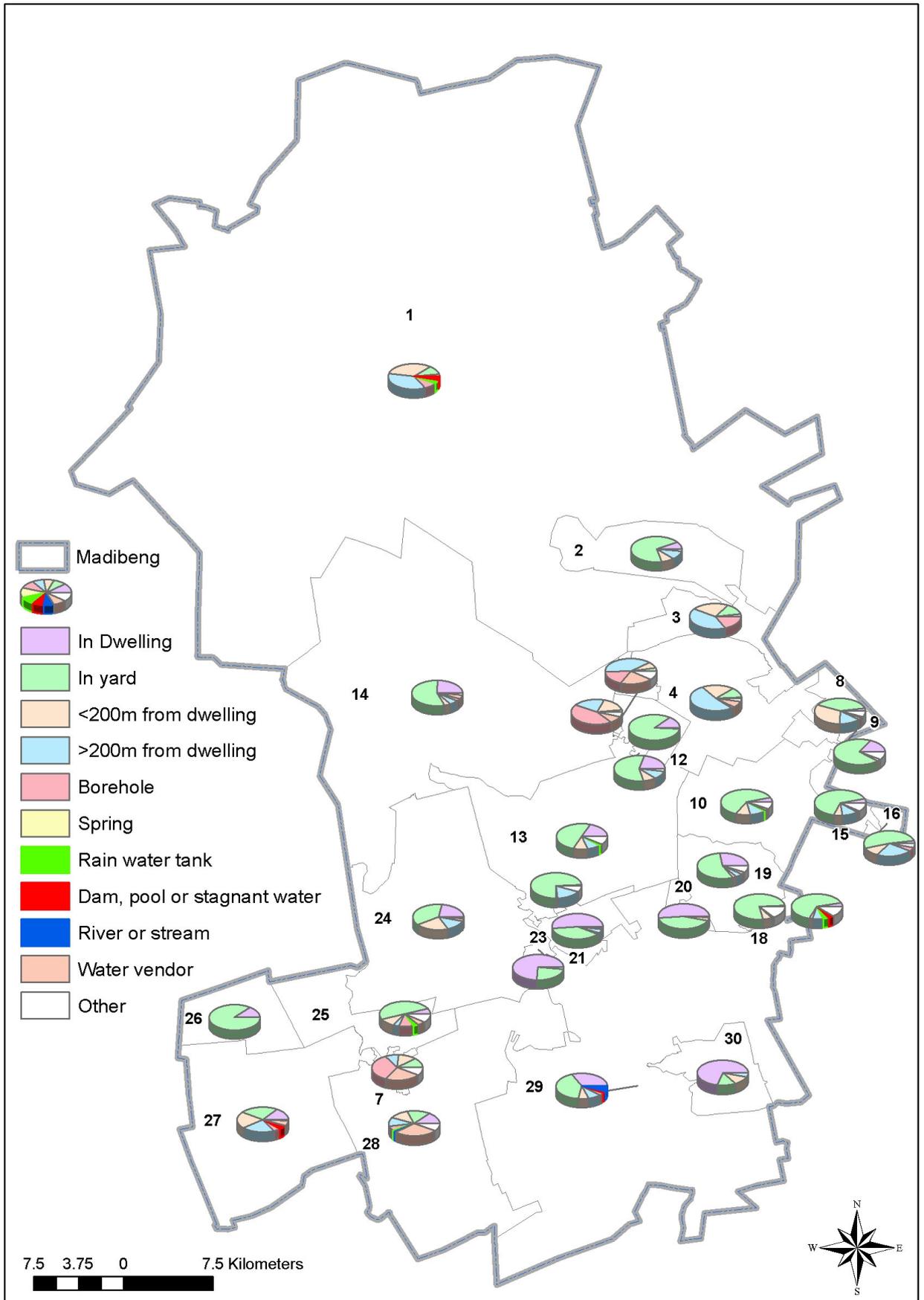


Figure 5-7: Madibeng water sources per ward.

Figure 5-7 shows the distribution of water sources per ward in Madibeng. Although relatively few people use natural sources, there are quite a number of people whose main source of drinking water is boreholes. People using natural sources and boreholes are at risk of pollution, especially in Madibeng where there are large numbers of potential polluters, such as mines and agriculture. People depending on rain water tanks will be at risk of water shortages during times of drought.

It is noteworthy that the poorer communities in the central and Northern regions of Madibeng do not have running water in their dwellings, but most use public facilities. It is also worth noting that communities with higher income levels have better access to running water.

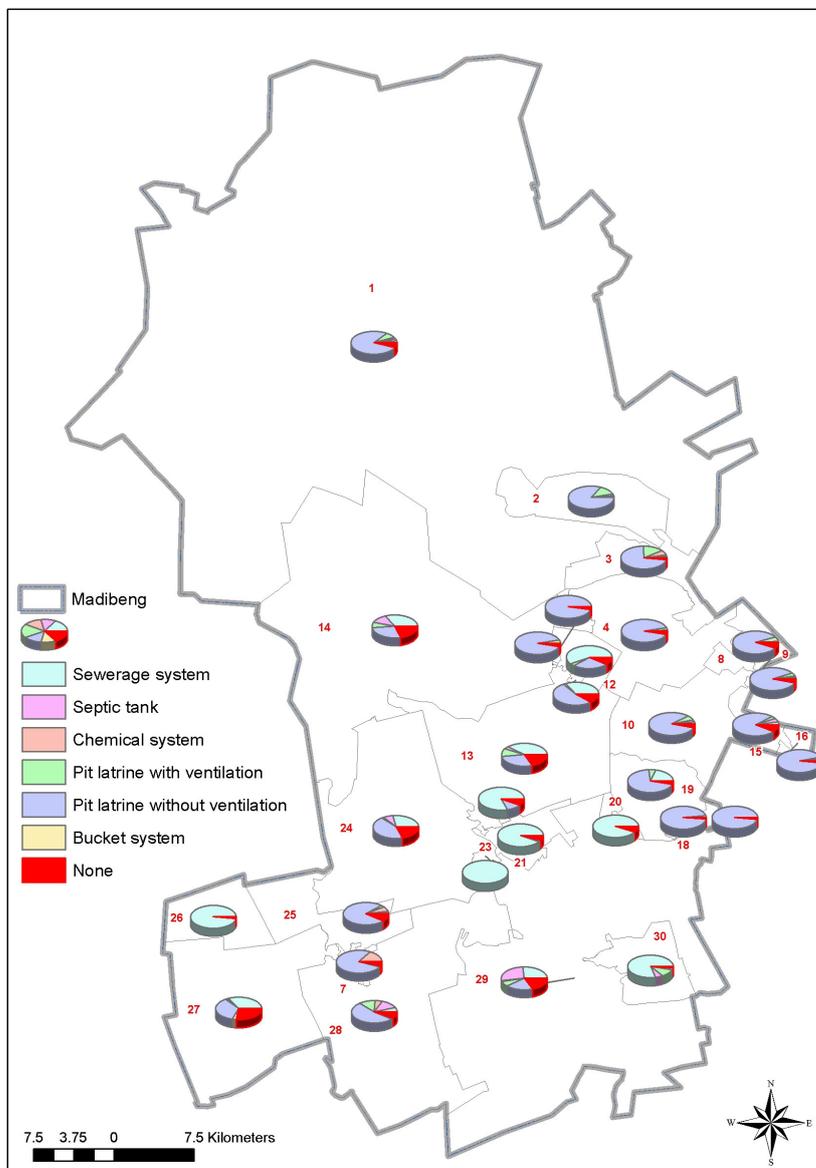


Figure 5-8: Madibeng sanitation facilities per ward.

Figure 5-8 indicates the distribution of types of sanitation facilities used by the households in Madibeng per ward. It is of great concern that such large numbers of households are using pit latrines, and in some cases do not have any facility. Especially in the eastern wards, which were previously shown to have the highest population density, most of the households use pit latrines. This situation can have serious impacts on the quality of natural water sources in the area.

Unfortunately there is no data available on waterborne disease for Madibeng that could be compared to the types of sanitation used and the sources of drinking water to see if there is any correlation between the health of these communities and the water and sanitation infrastructure.

- **Electricity**

‘Energy poverty’ is the condition of having less than a certain level of daily energy consumption necessary to maintain a minimum standard of living. This results in various negative impacts on nutrition through food preparation, hygiene, health and warmth. In addition, energy poverty limits the ability of a household to engage in a variety of economic opportunities (Throssel, 2002).

Energy is divided into three sub-sectors: electricity, hydro-carbon (including coal, gas and paraffin), and biomass (wood, dung and crop waste). In South Africa, most of the poor meet their energy needs using biomass fuels, or a combination of biomass and hydrocarbon fuels, and sometimes electricity. This multiple fuel use or fuel-switching is a characteristic of poor households (World Bank, 2000).

According to the National poverty and inequality report, forty four percent of South African households use paraffin every day, making it the most widely used commercial fuel in urban and rural areas. Although this was not found to be the case in Madibeng, according to the census data, it certainly is clear that large numbers of households do not have access to electricity. No data was available on the use of biomass as fuel source, but it could be assumed that many households are using biomass as an energy source as the use of electricity, gas and paraffin is relatively low in many wards.

However, there are serious safety and health issues connected with hydrocarbon and biomass use, such as fire hazards and paraffin poisoning of children, while especially biomass fuels can be a source of air pollution that could lead to respiratory disorders.

Many of the very poor in urban or rural areas are dependent on biomass fuels. Again the accumulation of these fuels is a labour intensive and time constraining exercise that could be avoided with electricity provision. Large-scale use of biomass as an energy source can also impact negatively on the environment, especially where vegetation is burned at a rate that is not sustainable (World Bank, 2000).

- **Road Infrastructure**

Transport is a significant factor in the development of health and education programmes, and is essential in stimulating and maintaining small enterprises and commercial activity. In addition, the length of time spent commuting daily could have been spent on income generation or other productive activities (Naude, 1999).

Accessibility to transport services for the poor is limited in the extent and location of services provided, and poorer groups especially in South Africa are often required to use more than one mode of transport to reach their destinations. People with disabilities are a particularly vulnerable group, as a lack of efficient transport effectively excludes them from most economic activities. In addition, the safety and security of passengers differ according to the modes of transport available (Baxter, 1989).

Road transport is the dominant mode of transport in South Africa, and investment in roads constitutes a major part of the government's capital stock. According to the Arrive Alive Campaign in 2002, the replacement cost of the rural road network was estimated at R130 billion and more than half the country's road network had exceeded its 20-year design life span.

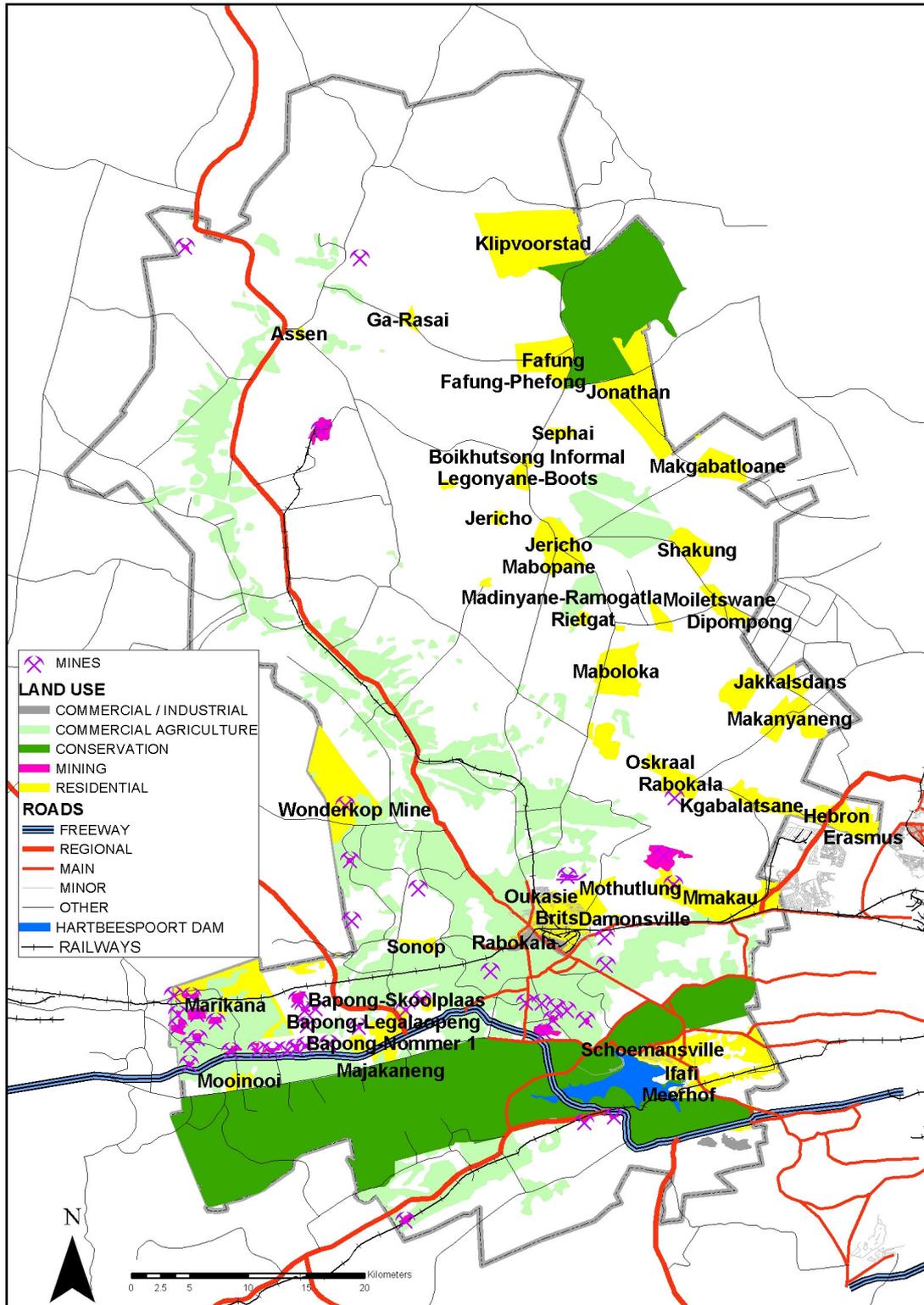


Figure 5-9: Madibeng road and rail infrastructure.

The road infrastructure in the southern part of Madibeng is relatively well-developed, as can be seen on Figure 5-9. The N4 national road (also known as the Platinum Highway) from Pretoria to Rustenburg passes through this area and attracts many small businesses.

The central and northern areas do not seem to be serviced as well as the southern area. This could be attributed to the higher concentration of commercial activities in the south. Unfortunately no data could be gathered on the state of the public transport system in Madibeng.

The nature of public transport in South Africa has also been greatly influenced by the Apartheid System. The unnatural layout of many towns and cities in South Africa means that many people have to travel large distances to and from work. Usually it is the poor that are worst affected, as they cannot afford high transport costs (Cadle and Fieldwick, 1992).

The taxi service is the most available mode of transport to the majority of the poor in South Africa, and this is the case in Madibeng as well. The government does not provide the taxi industry with subsidies, therefore it is impossible for existing transport subsidies to benefit the poorest of the poor.

- **Communications**

Communications are not necessarily a basic human need, but reliable telecommunications provide access to information, employment opportunities, education and health facilities, that will boost productivity and will have a positive impact on the ability of individuals and households to participate productively in the economic markets (Corbett, 2004).

Communication facilities are also vital in pre-warning systems for disaster management purposes and access to telephones could reduce people's vulnerability to hazards such as crime and disease as it would be possible for them to get the necessary support in a more efficient manner.

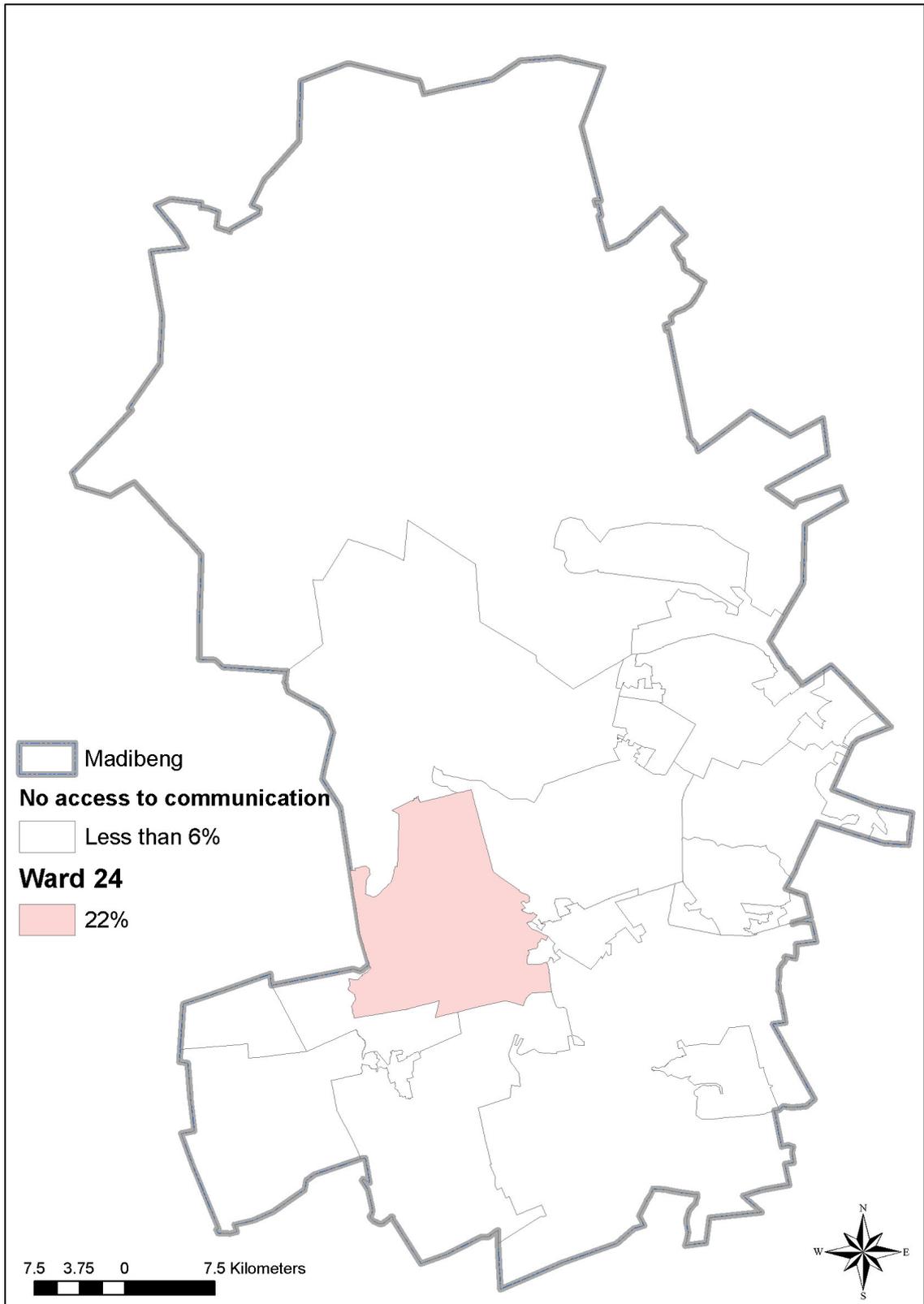


Figure 5-10: Telephone ownership per ward in Madibeng.

In South Africa only one percent of rural households have a telephone, compared with thirty two percent of urban households (World Bank, 2000). As the information in this study was provided on ward level, it is not possible to distinguish between urban and rural households. The average phone ownership in Madibeng is thirty six percent according to the 2001 Census.

Figure 5-10 indicates the percentage of households per ward in Madibeng that have no access to a telephone. As the information is given per ward, it is not possible to distinguish between urban and rural households. In most wards access to telephones are good with less than six percent of the population not having access. Only in ward 24, almost a quarter of the population do not have access to telephones.

5.1.4 Vulnerability Assessment

People that are most at risk of poverty are the ones that are traditionally most vulnerable. Poverty disproportionately affects women, children, the elderly and people with disabilities. In many developing nations, women have low social status and are restricted in their access to both education and income-generating work. Without adequate income, they commonly depend on men for support, which increases their vulnerability (Ileffe, 1987).

Most studies that compare poverty with demography reveal that the risk of poverty varies with age. The young and the old are most at risk, while the risks for families are higher than those of single, young and healthy individuals. The reason for this is obvious, as children do not have the opportunity to earn money and could be a burden to parents with low income. The elderly also have limited opportunities of earning and are often dependant on welfare, while young single individuals are capable of doing a variety of physical labour that would be impossible for children or the weak (Alcock, 1993).

People who do not work, such as young children, the elderly, and many people with disabilities, depend on families and other support networks for basic necessities. However, neither poor families nor the governments of many developing countries can adequately support the non-working. Poor children in particular suffer the consequences. Children have underdeveloped immune systems, and they easily acquire diseases in

unsanitary living conditions. Therefore the poorest countries have the highest rates of child morbidity (disease) and mortality (Colgan, 2002).

Many children are forced to leave school to care for family members, to earn money to support family or even to do tasks such as collecting firewood and water for the household. Their lack of education puts them at risk of poverty again when they are grown up and trying to enter the labour market (Gama, 2002).

Teenage school leavers are also a group that is extremely vulnerable to poverty. Many of these people have difficulty in finding employment as they do not have the experience wanted by employers, or the skills to successfully start their own enterprises. Many of these teenagers are forced to work for very little or no income (O'Connor, 1991).

Women are also more likely to be poor than men, mainly because of lower wages. The poverty rate among female-headed households is sixty percent, compared with thirty one percent for male-headed households. There has also been an increase in the number of single parent households due to marital breakdown in the last couple of decades, which contributes to a higher number of female-headed households (O'Connor, 1991; Alcock, 1993).

The persistence of poverty in rural areas can also be due to 'poverty traps', such as a lack of complementary assets and services resulting in 'poverty of opportunity', whereby individuals are unable to take full advantage of the few assets to which they have access. For example, a person might be able to afford an electrical power tool that could generate income or save time, but does not have access to electricity.

Poverty levels are also higher in rural areas, where agricultural workers are among the poorest of households. Average wages in agriculture are well below the minimum living level and farm workers find it difficult to switch to other sectors of employment. Farm workers are also more vulnerable as they are in many cases totally dependent on their employer for housing, water, electricity, transport and health care (Corbett, 2004).

Mineworkers are also a vulnerable group. Wages for mineworkers are traditionally lower than those for industry and manufacturing and the mining sector itself has experienced

major economical setbacks that has impacted directly on the labour force. In the past, many mineworkers migrated to the mines from the homelands and neighbouring countries. With the new constitution in place many of these workers have settled in mining areas in search of permanent employment, putting enormous strain on local resources.

Poverty is not only a direct hazard to the well-being of a community, but it also increases the vulnerability of communities to other hazardous events. Poor communities might have difficulty in protecting themselves from hazards, and when such events occur, they are more disrupted and will take longer to recover because of a lack of resources (World Bank, 2000).

When disaster strikes it is usually the poor that are most affected as they are less capable of coping with the impacts of a disaster. Very often a disaster may destroy all the material property of poor communities as they seldom have bank accounts with reserves saved up or even basic insurance.

Poor people often put themselves at risk when they occupy areas of land that are considered hazardous, because of a lack of land to live on close to urban areas. An example is the 6000 squatters living within the 1:50 year flood line of the Jukskei river in Alexandra, Johannesburg. There is thus not only a need for land, but also for non-hazardous land.

5.1.5 Summary

A large percentage of Madibeng's households live in conditions of extreme poverty, many without proper housing, water supply, sanitation or waste disposal services. Many also have limited access to health care and education. The challenge for the Madibeng Municipality is to improve the quality of life for these people, without depleting the available natural resources in the Municipality.

This can only be achieved through the sustainable use of a healthy natural environment that can supply raw materials, absorb and treat waste products, and maintain water, soil

and air quality. Food security, water provision and climatic stability depend on having properly functioning ecosystems, maintained levels of bio-diversity, sustainable rates of resource extraction, and a minimal production of waste and pollution (Walmsley, 2002).

Poverty is probably the most complex of hazards, as it interacts with so many different elements. To mitigate the effects of poverty it is therefore necessary to follow a holistic approach that addresses a variety of issues leading to a common goal. For example, improving the health of people improves their well-being and ability to work and earn money. Improved education also improves income potential and awareness of health, also leading to improved well-being and income generating potential.

Because the assessment of quality of life in South Africa cannot only be done via income levels alone, it is extremely important to have information on the other elements that are associated with the well-being of communities. Detailed information on infrastructure, the environment and demography of a community is needed to assess the real status of poverty.

As was previously explained, the availability of information is extremely important in the assessment of the risk of poverty. Although a lot of quality data was available for Madibeng, there is still a huge lack of information, such as information on disease that is area specific, detailed information on structure types and building materials and the availability and quality of basic services.

If poverty in South Africa is to be addressed then we also need to enforce strict environmental management policies. The benefits of efficient environmental management will impact positively on the poor, as they are the group living closest to the environment.

5.2 HAZARDOUS MATERIALS

As was discussed in the section on poverty, one of the greatest challenges for Madibeng and South Africa is to improve the quality of human life for both present and future generations, without depleting the country's natural resources. This can only be achieved through a healthy natural environment, which supplies raw materials, absorbs and treats waste products, and maintains water, soil and air quality (Walmsley, 2002).

Humans have the ability both to alter their environment and also to respond to it. This ability both creates and reduces or avoids certain risks. During the last century technology made profound advances, but unfortunately these advances have also been accompanied by the potential to cause catastrophic and long-lasting damage to life on Earth (Lofstedt and Frewer, 1998).

Technological risks are very often the most difficult and unpredictable to assess and are therefore difficult to understand in many cases, which in turn negatively influences people's perception of these risks. Nuclear power, for instance, is a good example of a risk that is very often exaggerated. The department of Engineering and Public Policy of the Carnegie Mellon University in Pittsburgh Pennsylvania, found that the risk of contracting cancer by living on the boundary of a nuclear power plant equals the risk of contracting cancer by eating 40 tablespoons of peanut butter (Barrow, 1997).

Industrial activities all over the world generate large volumes of hazardous waste and by-products that need to be stored, transported or disposed of safely (Johnson, 1999). As there are quite a number of industries and mines in the Madibeng Municipality and the fact that pollution was frequently mentioned as a hazard in the completed questionnaires and in interviews with local stakeholders, it became clear that hazardous materials pose a serious threat to the environment and community of Madibeng.

A substance may be considered hazardous if it is flammable, explosive, toxic, corrosive, radioactive and cryogenic, or readily decomposes to give off oxygen at elevated temperatures. There are thousands of substances that possess one or more of these qualities and can therefore be considered as hazardous. Multiple hazards can be

associated with many substances and the intermixing of chemicals can further complicate the behaviour and hazardousness of a substance (Irvin and Strong, 1997).

Compressed gases are especially hazardous as they often involve multiple hazards, such as poisons, oxidizers, cryogenics and the hazard of the pressure in the storage container itself. If the container fails it could be turned into a projectile or an explosive device. Flammable liquids are slightly less hazardous than gases, but are the cause of more incidents as they are more abundant. Commonly encountered flammable liquids include: petrol, oil, diesel, paraffin, benzene, alcohols, pesticides and jet fuel (Burke, 2003).

The United States Environmental Protection Agency recommends that a worst-case scenario is used in the hazard and vulnerability assessments of hazardous materials as it is often difficult to make exact predictions as to the extent of a potential incident.

5.2.1 Hazard Identification

5.2.1.1 Hazardous materials (hazmat) facilities

The Fire Brigade of Madibeng has identified industries, fuel stations and electrical substations in Brits that could pose a potential threat to the community, through production processes or the storage of potentially hazardous materials on site. Although most of these facilities have indicated that prevention and precaution management plans are in place, it is still necessary to indicate the potential hazard that these locations pose to the general community.

Figure 5-11 indicates the locations of hazardous locations in Brits, which could pose a threat to the community. Fuel stations can be seen as a hazard due to the large volume of fuel being stored on site, while electrical substations contain large amounts of oil for cooling purposes that could cause a large explosion should the oil overheat.

The following hazardous locations are all located in the industrial area of Brits and are indicated and numbered in Figure 5-11:

1 Syngeta

Situated in the industrial area of Brits, this business stores a very large volume of flammable liquids, approximately 600 000 litres. Syngeta also uses substances that are poisonous and could pose a pollution threat to the environment.

2 A.T.C.

A.T.C. is also situated in the industrial area of Brits and stores approximately 8 000 litres of nitrogen on site in a mobile tanker.

3 Auto Cast

This business is also situated in the industrial area of Brits and has the capacity to store a 100 000 liters of liquefied petroleum gas (LPG) in a surface tank. Ignition of this gas would lead to a huge explosion.

4. Color X.

Color X is situated in the industrial area of Brits and poses a threat of a huge explosion due to the storage of a maximum of 55 000 litres of hexane gas on site. This industry also poses a potential threat to the environment and there has been an incident in the past where gas bottles caught fire.

5 Natural Extraction.

Natural Extraction stores a maximum of 25 000 litres of hexane gas on site and could also pose a potential threat to the environment.

6 Lumex

Lumex stores around 6 000 litres of LPG gas in a surface tank and poses the risk of a mass explosion. Lumex is situated in the industrial area of Brits.

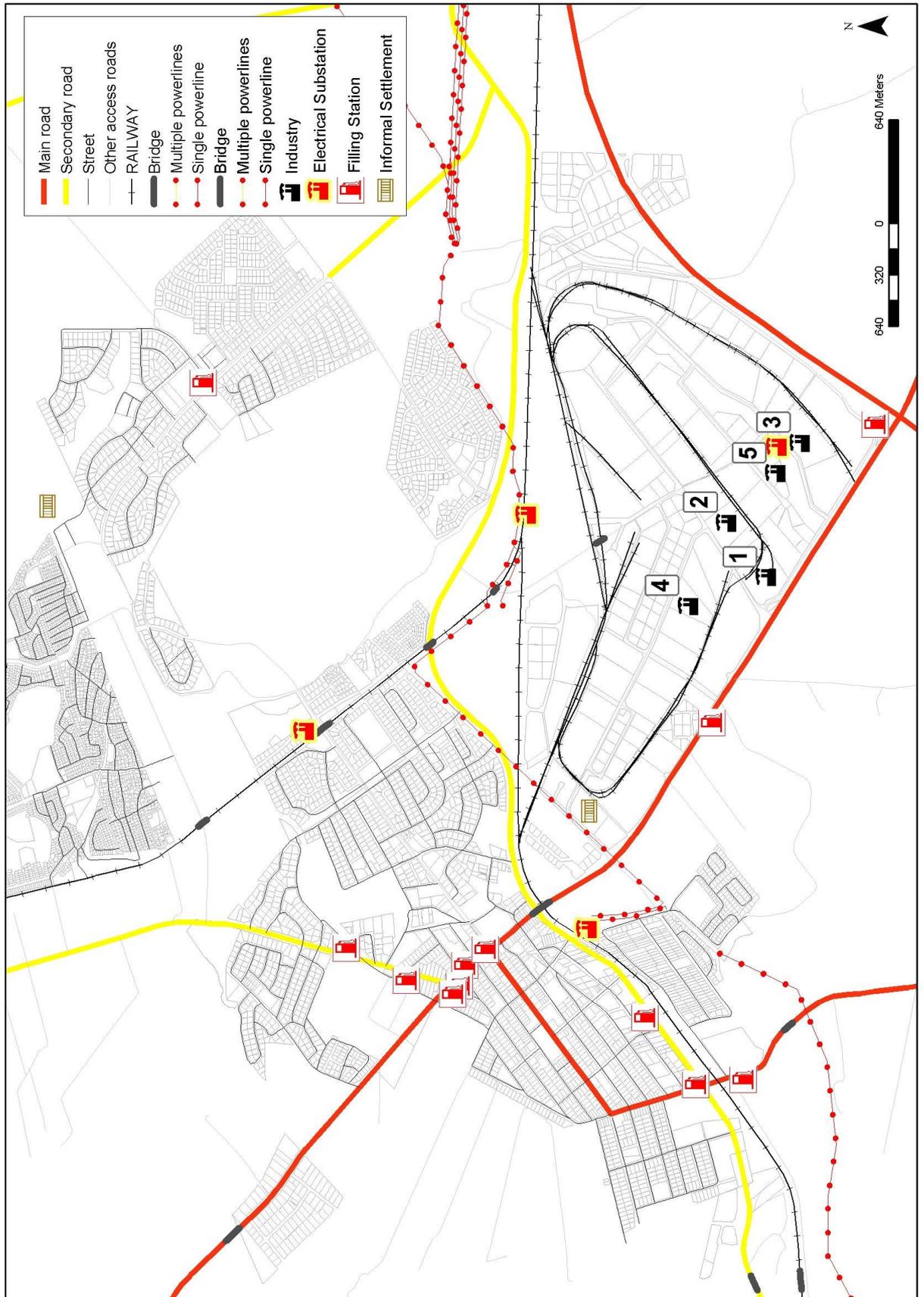


Figure 5-11: Brits hazardous materials facilities

These are only industries identified by the local fire brigade, but there are other industries in Madibeng that also store or use hazardous materials, such as fuel stations and mines. The Heric Ferrochrome facility close to Brits was responsible for a minor chrome 6 spill, for example. Chrome 6 is produced as a by-product in the smelting process and is highly toxic. Slimes dams can also be a major hazard, as was illustrated in the Merriespruit disaster on 22 February 1994 (Disaster Management Green Paper). Figure 5-12 indicates the locations of mines and slimes dams in Madibeng.

Figure 5-11 also indicates high voltage electrical cables that can be considered as hazardous. It is important to keep electricity servitudes free of obstacles such as trees and buildings that can come into contact with the cables and cause fire. Power lines that are damaged during extreme weather conditions or accidents also pose a major fire hazard.

Necsa (indicated on Figure 5-13) is a state-owned company that specialises in the areas of nuclear science and technology, fluorine chemistry and engineering. It was formerly known as the Atomic Energy Corporation (AEC). Necsa owns a large tract of freehold land at Pelindaba within the Madibeng Local Municipality, where it houses and operates a nuclear research reactor, known as SAFARI-1, the largest hydrofluoric acid plant in the Southern Hemisphere, waste management and various other facilities of strategic national importance.

SAFARI-1 is used to produce radioisotopes for medical and industrial purposes and to perform the doping of silicon by nuclear transmutation for the semiconductor industry.

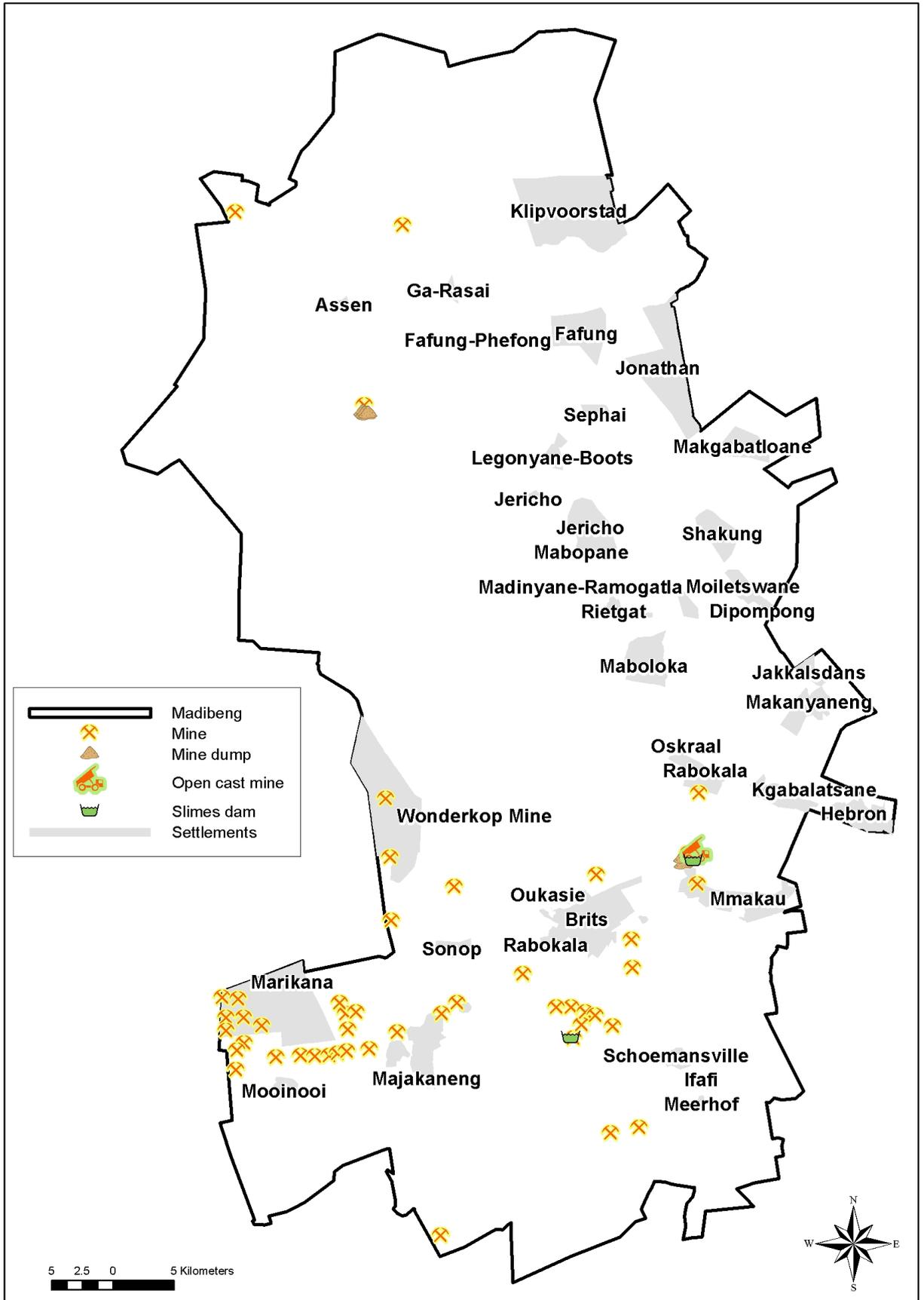


Figure 5-12: Madibeng mines and slimes dams.

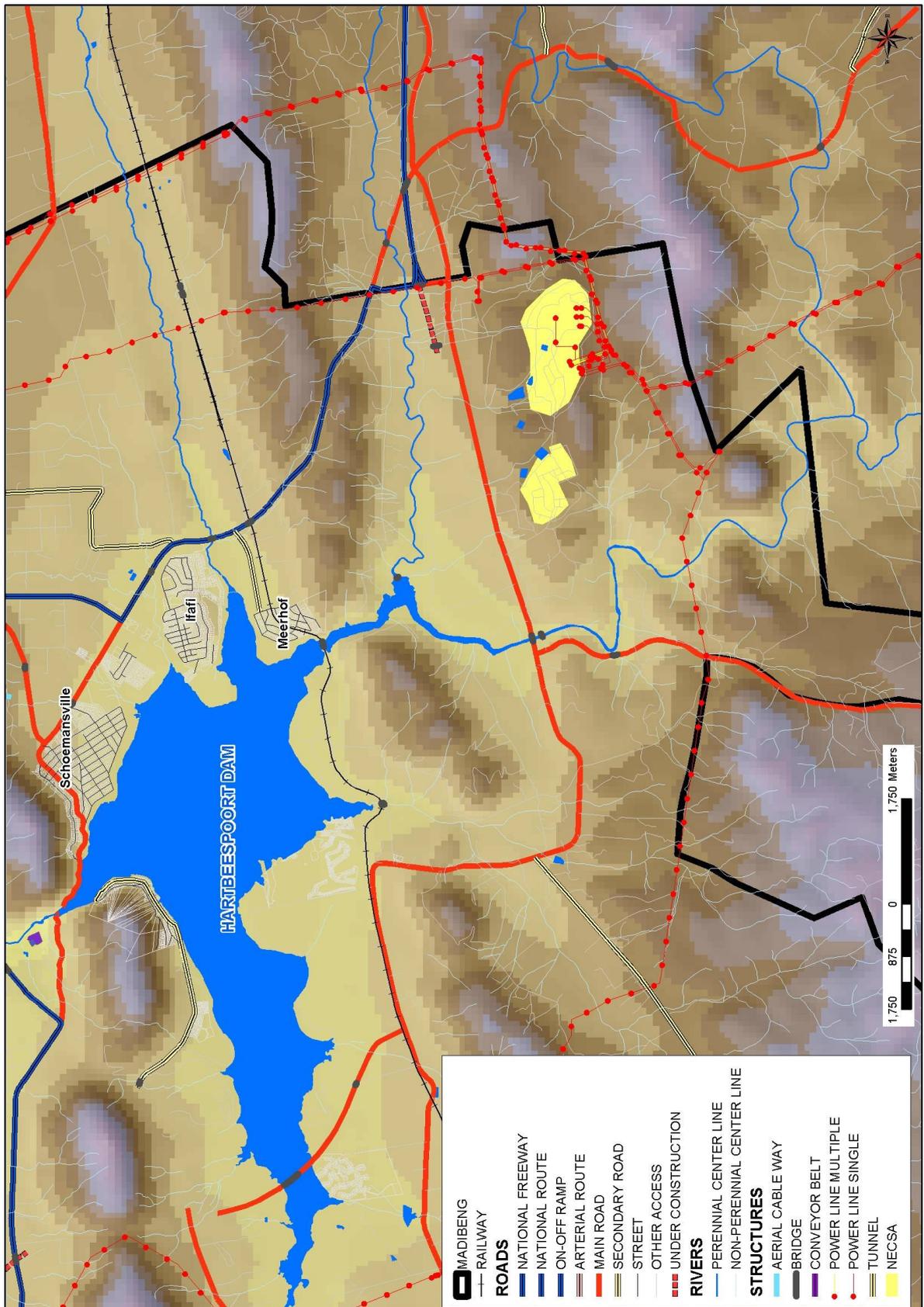


Figure 5-13: Necsa

5.2.1.2 HAZMAT transportation

Hazardous materials are also transported via road and railway in Madibeng. Unfortunately there is no information on the exact routes used to transport specific materials, but it was assumed that all major roads in Madibeng are used for this purpose. Railways are also frequently used for the mass transportation of hazardous materials.

Because of a variety of external factors, such as road conditions and human error, the transportation of hazmat carries more risk than storage and daily operations in hazmat facilities where a controlled environment can reduce the risk of accidents. Major roads and railways were therefore also identified as areas in which hazmat incidents are likely to occur and they are indicated in Figure 5-14.

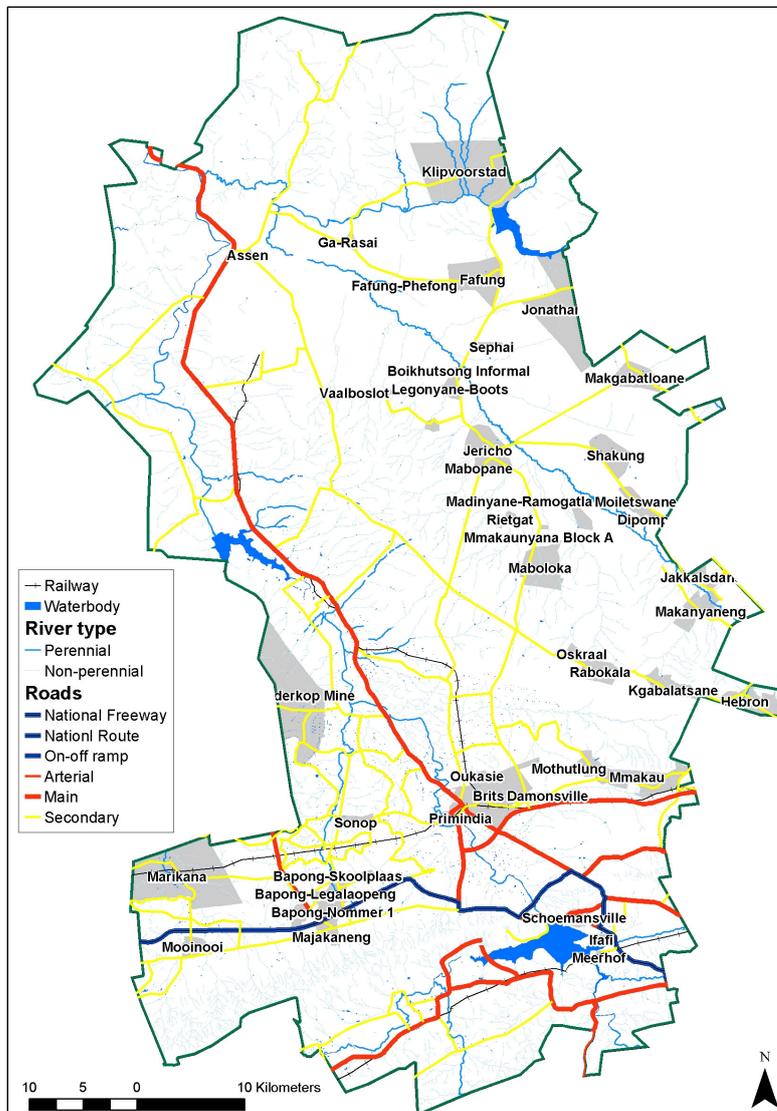


Figure 5-14: Hazmat transportation routes.

5.2.2 Hazmat Risk and Vulnerability Assessment

5.2.2.1 Hazmat facilities

Hazmat incidences can cause extensive damage to infrastructure and the environment especially through fire and pollution, leading to great economic losses. Most industries take all possible precautionary steps to prevent an incident and are usually forced by legislation to have emergency preparedness plans in place. Notwithstanding this, hazmat incidents are still fairly common and account for the majority of human induced disaster events worldwide.

An extreme example is taken from the town of Kingman, Arizona, in the United States of America. A 33 500 gallon railroad tank car containing liquefied petroleum gas was being offloaded at a distribution plant. The tank developed a leak and during the effort to repair the leak a fire occurred. One worker was killed and another injured. The help of the fire department was then called in. Shortly after the fire department's arrival, the tank ruptured and gas came into contact with open flames causing a mass explosion. The 20 ton railcar was propelled 1 200 feet by the explosion, killing 12 firemen and injuring 95 spectators. The blast also set fire to other businesses within a 900 foot radius, including a tyre company and lumber supplier (Burke, 2003).

A community's vulnerability to these types of incidents depends on the demographic and economic factors of that community. Old people, children and disabled people are more at risk, because of their physical inability to evacuate an area or extinguish a fire. Poorer communities do not always have the resources to deal with a fire or a more complicated hazmat incident. They also make use of hazardous materials for fuel, live in structures that might be more susceptible to fire and live closer together. The increase in population density, poor building structures and increased density of structures, means that in the event of fire, more people are at risk and it becomes more difficult to fight a fire in such areas.

The impacts of a hazmat incident on these communities are also potentially more severe as the communities do not necessarily have the financial means to recover from such an event, because of the lack of insurance and savings.

Certain locations have been identified by Brits Emergency Services as sites where people are especially vulnerable to the threat of hazardous materials. These sites are usually associated with areas with a high population density, or with people that are ill or weakened and therefore unable to vacate a building during a disaster event.

The following sites are examples of places where people will have difficulties vacating the building on their own in Madibeng;

- 1) Rusoord Tehuis (old age home)
- 2) Brits Mediclinic
- 3) Brits Provincial Hospital

The following are buildings with multiple storeys and/or which attract high concentrations of people and could be vulnerable during a fire:

- 1) Edelweisse Flats
- 2) Sieling Centre
- 3) City Gardens Building
- 4) Municipal Offices

Figure 5-15 indicates areas in Brits that are highly vulnerable because of their proximity to hazardous sites. The fuel stations in the south are in close proximity to each other and two hospitals are located close by, therefore increasing the vulnerability of people in these hospitals. Because these three filling stations are in such close proximity to each other, a fire or explosion at one site could easily spread to the others and lead to a major disaster.

In the industrial area of Brits a 1km buffer was used to identify areas at risk of a major event on the Syngenta site. The buffer is only given to indicate the relative proximity of hazardous locations and should not be seen as an area at risk of hazardous materials. As can be seen on Figure 5-16 there are no vulnerable land use types within the 1 km buffer, but the other high risk hazmat facilities are all located well inside this buffer. Such a major event could therefore have a potential domino effect that should be considered by emergency services when planning for such a disaster.

The high concentration of mining activities in Madibeng does put all communities in the area at high risk of air and water pollution. Unfortunately no accurate information could be gathered on the extent of any polluted areas, but local residents were very concerned about this problem.

Figure 5-17 is an example of an area that could potentially be at risk of hazmat pollution. This is a rural area where water is supplied from a series of reservoirs and fountains around the Rosespruit for irrigation purposes as well as human and animal consumption. A mine is situated upstream from the water sources and can therefore cause pollution should any chemicals be released or spilled into the local water system.

This figure illustrates how important it is to perform a detailed environmental impact assessment before granting mining rights and also of continued environmental audits to prevent or mitigate any potential pollution hazard.

Another potential source of pollution is Necsa, where radioactive waste is presently stored at Pelindaba in various locations on the site. The waste occurs in the form of low and intermediate level waste. Some of the waste is short-lived waste and some is long-lived waste.

Radioactive waste produced in the Hot Cell Complex and Isotope Production Centre at Necsa is also stored on site. Historical waste, consisting of combinations of low and intermediate level waste as well as spent radiation sources, is also stored in covered trenches at Thabana on the Pelindaba site.

The pollution hazard, combined with the threat of an active nuclear reactor, makes Necsa a highly hazardous location. Necsa were approached to gather information on areas that are potentially at risk of a major incident on the site. According to Necsa, a 5km buffer (Figure 5-18) would be sufficient for Disaster Management's planning purposes, but no official information such as risk assessments have been received.

The recommended 5km buffer hardly seems sufficient to identify communities at risk of a nuclear type accident. Only the community of Meerhof is located within this buffer.

Rivers and streams close to the facility are also at risk of pollution. These streams flow into the Hartbeespoortdam and therefore could potentially put a very large area at risk of radioactive pollution.

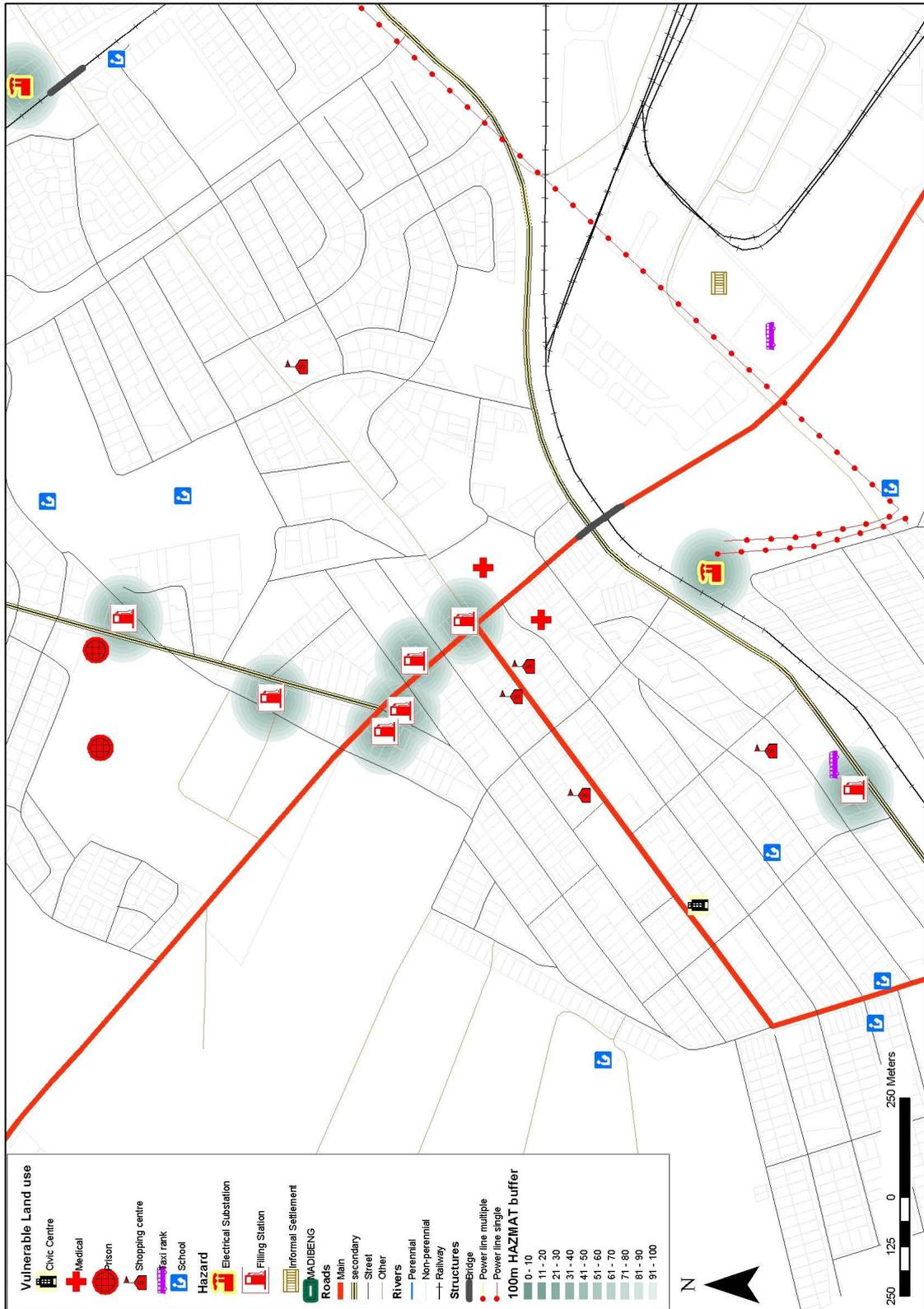


Figure 5-15: Vulnerable locations to hazmat incidents

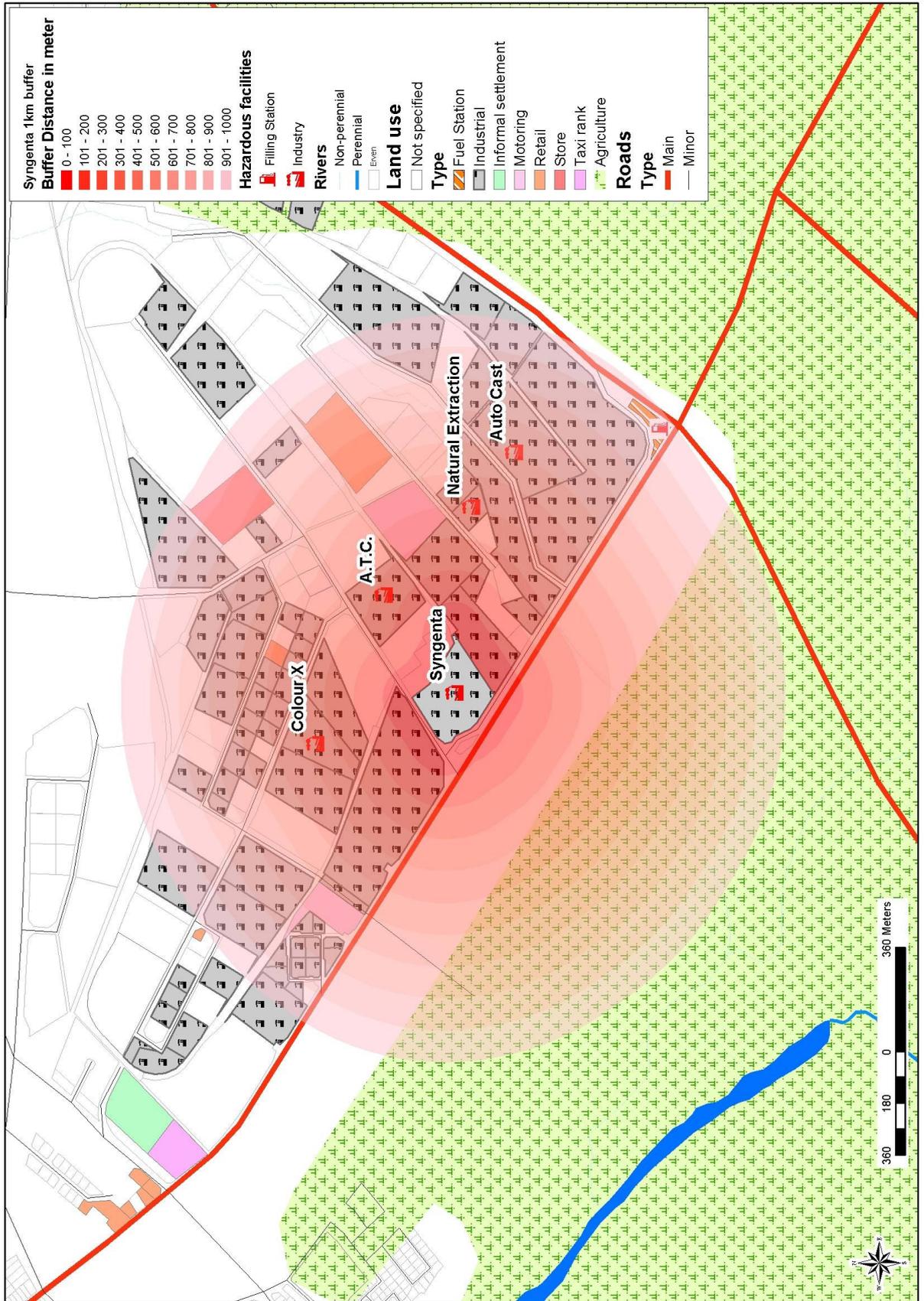


Figure 5-16: Brits industrial area hazmat vulnerability

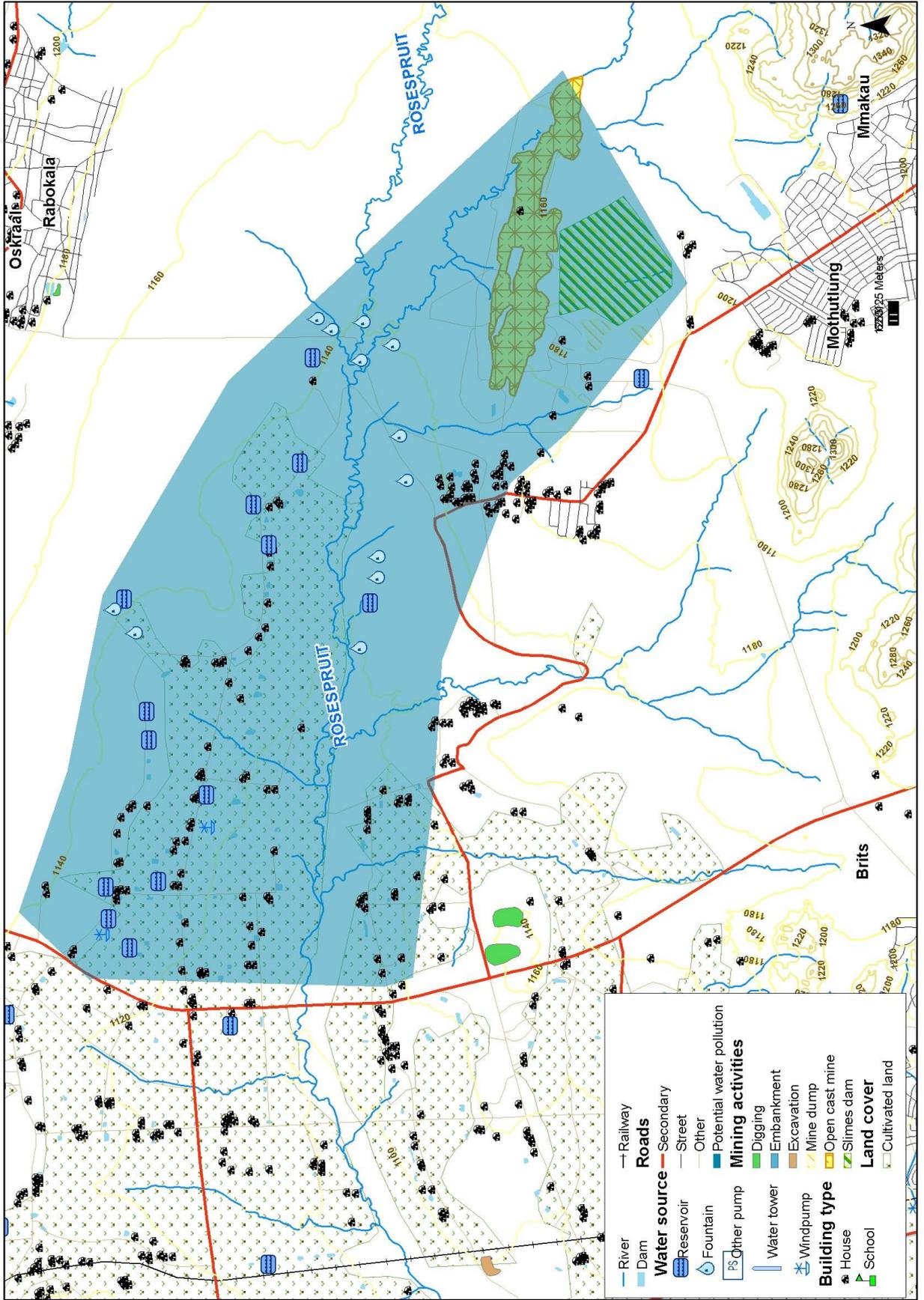


Figure 5-17: Mine pollution risk

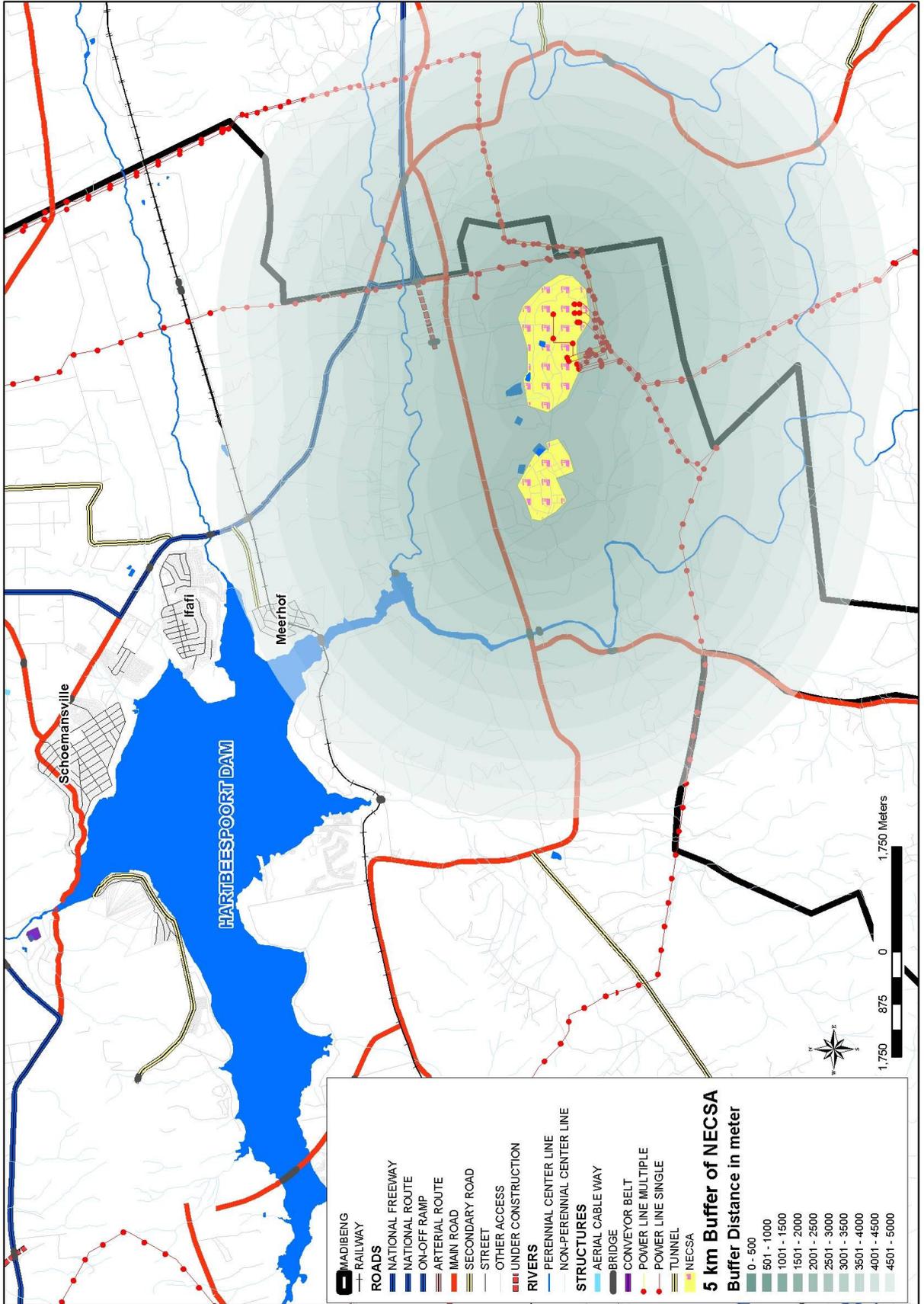


Figure 5-18: Necsca risk area

5.2.2.2 Hazmat Transportation

Hazardous materials are transported on our roads and railways on a regular basis and accidents involving these substances are not uncommon. Accidents involving hazmat can cause pollution of soil and water and in extreme cases threaten the lives of people.

Hazardous chemical releases that happen on land are generally not as serious as accidents in water resources. Chemicals released on land will not travel as fast as a spill in water, however, in soils that are porous there could be rapid vertical movement and eventually contamination of groundwater (Irvin and Strong, 1997).

In built-up areas it is also possible that hazardous materials can spill into the stormwater drainage system that makes containment difficult and then later also into natural water sources that are connected to the stormwater system (Burke, 2003).

Areas at risk of hazmat incidents on roads have been indicated with a buffer of 100 metres (Figure 5-19). Areas at risk of hazmat incidents on railway lines have been indicated with a 1km buffer, because railway incidents could potentially have a much bigger impact as trains are able to transport much larger quantities of hazardous materials than trucks can (Figure 5-20). Again these buffers are merely designed to indicate the relative proximity of communities to hazards and do not indicate areas at risk.

With the use of GIS it is possible to identify locations where a hazmat incident may lead to the contamination of water. All locations where hazmat routes cross rivers are indicated with red stars in Figures 5-19 and 5-20. Figure 5-19 also indicates the locations of groundwater resources that could be at risk of hazmat spills.

The following communities indicated in Table 5-1, are located within 100 metres of potential hazardous materials transport routes:

Table 5-1: Communities at risk of hazmat transportation by road

Bapong Legalaopeng	Tornado-Modderspruit	Klipvoorstad
Bapong-Newtown	Vaalboslot	Legonyane-Boots
Bapong-Nommer 1	Wonderkop Mine	Maboloka
Bapong-Outstad	Assen	Mabopane

Bapong-Skoolplaas	Majakaneng	Madinyane
Boikhutsong Informal	Makanyaneng	Ifafi
Brits	Makgabatloane	Jakkalsdans
Damonsville	Marikana	Jericho
Dipompong	Meerhof	Jonathan
Erasmus	Mmakau	Kgabalatsane
Fafung	Moiletswane	Primindia
Fafung-Phefong	Mooinooi	Rabokala
Ga-Rasai	Mothutlung	Schoemansville
Hebron	Oskraal	Shakung
Sonop		

Communities that are located within 1km of railway lines are indicated in Table 5-2.

Table 5-2: Communities at risk of hazmat transportation by railway.

Brits
Damonsville
Hebron
Ifafi
Marikana
Meerhof
Mmakau
Oukasie
Primindia
Rabokala

Figure 5-21 indicates that almost the entire population of Brits is potentially at risk of hazmat incidents due to the transportation of hazardous materials. It is therefore extremely important to have emergency measures in place for all types of hazmat incidents. Information on the type and quantities of hazmat materials being transported in the area could also be useful in determining more accurate risk assessments.

Valuable information on hazmat that can also be added to the GIS, is firefighting recommendations specific to the hazmat involved, type of protective equipment, evacuation routes and safety zones.



Figure 5-19: Hazardous material transportation: roads

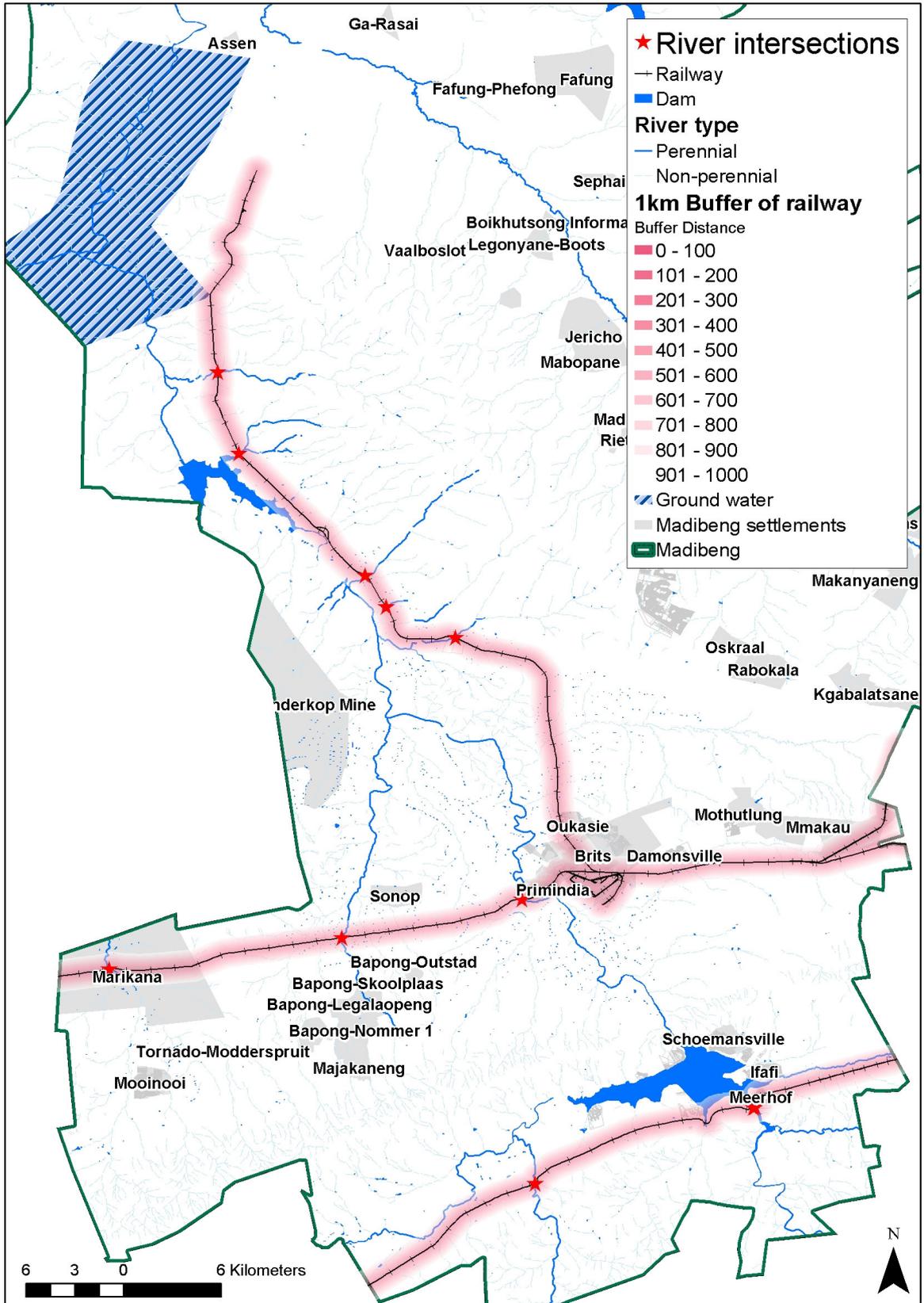


Figure 5-20: Hazardous material transportation: railway

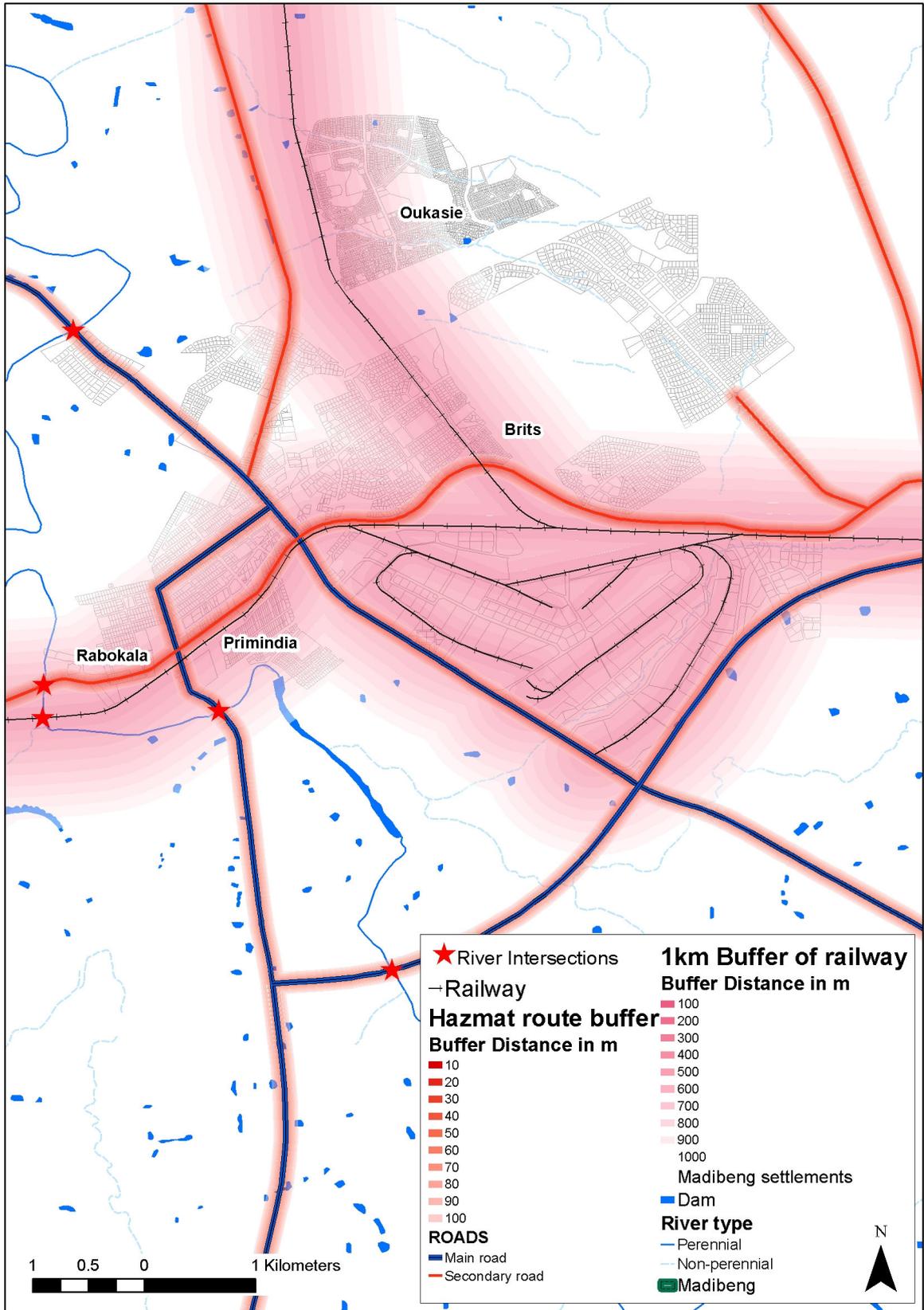


Figure 5-21: Brits hazmat routes

5.2.3 Summary

Although hazardous materials pose a very real threat to communities, very little information is available on the precise dangers that these substances pose and the risk associated with each. It is also of concern that so little is known in regard to the transportation of hazardous materials, as this action carries the highest risk of causing a future disaster.

The relatively high concentrations of mines and industry in Madibeng, coupled with the poor state of most roads in the area, puts the community of Madibeng at high risk of pollution from hazardous substances. An accident involving toxic chemicals could become a matter of serious concern for the residents of Madibeng.

Although environmental impact assessments of individual mines and other hazardous facilities indicate that these facilities do not exceed pollution thresholds stated by law, the cumulative impact that these facilities have in a relatively small geographic area are not known. Mines that were contacted for comment were also uncooperative and downplayed the potential of hazardous materials incidents occurring, even though there are recorded incidents in Madibeng.

Chapter 6: CONCLUSIONS AND RECOMMENDATIONS.

A Disaster Management Plan is one of the main documents that form part of every Municipality in South Africa's Integrated Development Plan, which in turn is aimed at sustainable development to ensure the prosperity of all communities and future generations. The Disaster Management Plan is therefore regarded as an important function of the management of a Municipality and it is required by law that each Local and District Municipality should prepare such a plan (Act 57 of 2002).

The new Disaster Management Act has highlighted a number of weaknesses in the management of Madibeng, especially concerning pro-active disaster management. Because of the new approach to disaster management, there is very little expertise in the field and no processes in place to perform pro-active disaster management.

New methodologies had to be developed to cope with this problem and GIS provides the logical solution. Roy Price, who is the past President of The United State's National Emergency Management Association, stated that GIS is the best method to support emergency management information needs. GIS provides the platform for widely diverse organizational and governmental agencies to participate in the full range of emergency management activities at all levels of government (Greene, 2002).

In the case of Madibeng, however, this solution is severely handicapped by a lack of information as is illustrated in this study. However disaster management cannot ignore its duties due to a lack of suitable information. While disaster management is waiting for perfect data, daily life continues and people out there remain at risk or vulnerable to disasters. GIS provides simple methods to perform basic risk and vulnerability assessments that could be used in compiling disaster management plans.

For effective disaster identification and mitigation, Madibeng needs a comprehensive and up-to-date hazard database coupled to an effective GIS. This will also assist in the post disaster recovery process, as was illustrated in the U.S.A. by the events of September 11.

6.1 GIS FOR DISASTER MANAGEMENT IN MADIBENG

The importance and advantages of a well functioning GIS for disaster management purposes is mentioned throughout this study. A GIS however consists of more than just data, but also hardware, software, processes and users. None of these elements are currently in place in Madibeng (Burrough and McDonnell 1998).

6.1.1 Data

Freely flowing interchange of data between organizations is one of the most important elements in the success of a GIS based disaster management operation. One of the problems found is that departments do not communicate on the availability of data. Different departments use different formats, and bureaucratic turf wars and the perception that data “belongs” to a department inhibits the availability of data (Longley et al., 2001).

As was found in this study, readily available data in the correct formats for use in a GIS is not sufficient to perform detailed risk and vulnerability assessments for all potential disasters in Madibeng. The gathering, capturing and maintenance of spatial data are not the responsibility of Disaster Management. However without spatial data it would be impossible to plan and manage disasters.

Ideally data should be available from all the different departments of the Municipality and other custodians of spatial data that is of relevance to Disaster Management, such as census, demarcation and cadastral data. In the case of Proactive Disaster Management the more data that can be gathered the better, as it is often not possible to predict what data could become useful in future. A good example from September 11 is the location of animal shelters, as many of the people that died in that disaster had pets at home that needed to be taken care of (Greene, 2002).

Disaster management could also promote or share in data capturing by other departments or organizations. For instance, some Municipalities use aerial photography to monitor urban sprawl and also in other projects where land cover is of importance.

These images are ideal background information and can also be used to capture data needed specifically by Disaster Management

The spatial properties and formats of data are also important factors to be considered. Standardized projections and formats, especially in using of Computer Aided Drawing (CAD) programs, could greatly improve the distribution of valuable data, as this would simplify the conversion process from CAD to GIS.

6.1.2 Processes

Processes in a GIS include gathering, capturing and cleaning of data; the methodologies used to perform different types of assessments or analysis and updating of the database (Longley et al., 2001). The nature of available data in Madibeng will have a major influence on the workflow process, as much of the work in this study was simply the gathering of suitable data and converting them to a usable format.

Although in most cases the methodology and technology needed to perform detailed hazard and vulnerability assessments with GIS already exist for most potential disasters, a lack of data and trained personnel hamper the use of these methodologies. It is also important that these methodologies be tested and kept up to date with current standards.

Updating of data is also an important process, as the environment and human movements continually change over time. If data are freely available in a standard format and methodologies for hazard and risk assessments are in place, the workflow process in the GIS would be much more simplified and in effect become an updating function.

6.1.3 Software

The choice of software has many implications for the success of any GIS. The first consideration would be the general functionality of the software. In the case of Madibeng relatively complex GIS software was needed, especially for cleaning of data and analysis purposes. If the available data were in a standard format and methodologies for hazard

and risk assessments in place, it would be possible to develop simpler customized GIS software that would cater specifically for the needs of Disaster Management.

There are a number of factors that would influence the choice of software to be used in Madibeng Local Municipality. These include:

- **Quality of data:** If data are of poor quality, as is the case in Madibeng, then more specialized GIS functions are needed to clean and process data. If a comprehensive spatial database existed it would be possible to develop custom software specifically aimed at the needs of decision makers in Disaster Management.
- **Compatibility:** Many Municipalities have their own GIS Departments or GIS sections within the different Municipal departments. It would therefore be logical for Madibeng Disaster Management to use software that is compatible with the data and software of other departments. The ability to publish data on the internet has also become an important consideration, as the sharing of geographic knowledge with the whole community is vital if mitigating disasters should be successful.
- **Human Resources:** The level of expertise of employees should also be considered as software that is too specialized could discourage employees from making use of it. In the case of Madibeng it would be advisable to employ at least one GIS expert to facilitate the more complex GIS functions needed.
- **Budget constraints:** Importantly, budget constraints could also influence the type of software used. In this case it would also be important to consider the future needs of more functions, for instance the possibility of publishing disaster maps on the internet. Short-term savings should therefore be weighted against long-term benefits.

6.1.4 Hardware

Hardware are the personal computers, networks, printers or plotters, Global Positioning System (GPS) units and other physical equipment needed to run an effective GIS. GIS data bases are generally very large and need powerful hardware to operate efficiently (Longley *et al.*, 2001).

In the case of a disaster scenario it is also important that sufficient backup hardware is available. Mobile hardware is very useful during a disaster and independent power sources will be needed to ensure that the GIS can function in areas where infrastructure is badly damaged.

GPS technology has also become a very useful tool in Disaster Management. These devices can be used to capture the locations of existing hazards, disaster and hazard events, and in the recovery phase they can be used to document the locations of bodies, debris and impact zones.

6.1.5 People

Users of GIS include the specialists compiling the databases, analysts using the information from the databases, decision makers and the general public that should have access to the valuable information gathered and produced using the GIS.

The success of a GIS is often determined by its acceptance by the users. It is therefore important that people are aware of the value of GIS and are involved in the whole system.

6.2 RECOMMENDATIONS

Clearly Madibeng Municipality does not have a functioning GIS that can be used by Disaster Management for decision making purposes. The value that GIS brings to disaster management, however, should make it viable to plan for independent GIS capabilities for the future.

It would not necessarily be the sole responsibility of Disaster Management to maintain a fully functioning GIS, but decision makers should be aware of the functionalities and advantages of using GIS. Madibeng Disaster Management should therefore promote the use of GIS throughout the municipality, as this would be advantageous to its own purposes.

The following specific issues regarding hazards that were identified in the preceding chapters need to be addressed by the Madibeng Municipality in order to manage potential disasters with GIS.

6.2.1 Floods:

Flood lines should be generated for any development where flooding is likely. These flood lines should be converted to a GIS format and stored in the municipal or disaster management database.

Flow velocity and depth of inundation are data that could be represented spatially and therefore be incorporated in a GIS. Land use data should generally be readily available in a spatial format. All Municipalities in South Africa have to generate spatial development frameworks for cities and towns in their areas of jurisdiction that could provide valuable land use information in the GIS.

Government's restructuring and development plans have also meant that large numbers of infrastructure projects have been undertaken countrywide over the last ten years. The planning of water and sanitation facilities involves the use of contour data that can in turn be used in the determination of depth of inundation and flow velocity.

6.2.2 Fire:

A detailed accurate fire management system for Madibeng would only be possible if sufficient reliable information is available to the disaster management manager. GIS can provide such a system for Madibeng with the following data and processes in place:

A detailed fire danger index needs to be developed for Madibeng in terms of the risk of fires occurring, number and size of fires that could be expected under certain conditions, their relative ease or difficulty to control, and the estimation of possible damage. Data that would be of vital importance for such a system includes the following:

- Climatic data
- Details on historic fire events
- Detailed land use and land cover information
- An accurate digital elevation model

6.2.3 Drought:

The assessment of drought risk in Madibeng encountered the same difficulties as experienced with the flood and fire risk scenarios. A lack of accurate, area specific climatic data generalizes the results of the study and these should only be regarded as a general guide in assessing the drought risk and vulnerability of Madibeng.

In the case of drought it would also be possible to compile a more accurate risk assessment model, given the correct data. It is important that such a model take into consideration the unique properties of the area, especially in a Municipality such as Madibeng with a wide variety of land cover and land use types and even relatively large climatic variables on such a small geographic extent.

As was explained in the drought report, people's vulnerability to drought is also influenced by other factors, such as the economic climate, that should also be considered in the development of a drought risk model. The following types of data would be of value to a drought risk model:

- Accurate, detailed climatic information
- Accurate and up-to-date land cover and land use information
- Accurate soil information
- Demographic data (To determine the community's dependency on agriculture)
- Economic data

6.2.4 Geological Hazards

Very little spatial data on geological hazards was available in Madibeng. This does not mean that Madibeng is not at risk of these hazards. Given the large number of mines in the municipality it is highly likely that more data is available on geological hazards that could be further investigated.

It is recommended that Madibeng Disaster Management investigate the probability of the formation of sinkholes in other areas not indicated in Chapter 4 as well as the risk associated with earthquakes in the area.

6.2.5 Poverty and Environmental Degradation

The aim of pro-active disaster management is to mitigate or reduce the risk of disasters. By reducing poverty and providing people with necessary infrastructure, vulnerability is reduced and therefore the risks of disasters happening also become less. Addressing poverty therefore reduces the risk of all other hazard events and should thus be seen as one of the most important actions in effective pro-active disaster management.

Poverty is probably the most complex of hazards, as it interacts with so many different elements. To mitigate the effects of poverty it is therefore necessary to follow a holistic approach that addresses a variety of issues leading to a common goal. As this report shows, GIS is a valuable tool in coordinating these different approaches in the fight against poverty

The availability of information is extremely important in the assessment of disaster risks. Most of the available data for Madibeng were received from the 2001 Census and therefore already outdated. There is still a huge lack in information, such as information on disease that is area specific, detailed information on structure types and building materials and the availability and quality of basic services.

There are a number of institutions that could be approached for poverty related data in order to perform more accurate disaster risk assessments for Madibeng. Some of these potential data sources are:

- Service providers such as ESKOM, TELKOM and DWAF. Data should be available on the extent of service delivery for Madibeng from these organisations.
- Department of health: Because of the sensitivity of health related data it was difficult to gather accurate data to be used in this study from the Health Services. Disaster management should, however, have the authority to negotiate terms for the sharing of health related data.
- Other surveyed data: Other organisations such as the World Bank, Statistics South Africa, marketing agencies and banks also capture social data from time to time that could be of value to disaster management.

6.2.6 Hazardous Materials

As stated before, hazardous materials incidents have become the most common hazard events that threaten communities. The nature of hazardous chemicals coupled with human error increases the probability of a hazardous materials related disaster.

GIS related actions that could be implemented in managing the potential risk of hazardous materials include the identification and mapping of all locations associated with hazardous materials, mapping routes used to transport hazardous materials and linking as much related data to these spatial entities as possible.

Hazardous materials related data that could be of value and need to be gathered by Madibeng include the following:

- Quantity and types of hazardous material being stored, produced or transported.
- High risk locations on transportation routes such as river crossings, high accident zones and highly populated areas.
- Chemical properties of materials stored or transported to facilitate planning and reactive procedures.

6.3 SUMMARY

GIS has the capability to provide Madibeng Local Municipality with a structured, cost effective system for the implementation of the requirements as set out in the Disaster Management Act of 2002. The variety of hazards and the complexity of relationships between hazards and communities' vulnerability makes GIS the logical tool to be used by disaster management in disaster risk reduction strategies.

The lack of suitable spatial data made it impossible to perform accurate disaster risk and vulnerability assessments for Madibeng. This is worrying as the lack of data does not reflect on the ability of GIS as a disaster management tool, but rather stresses the fact that pro-active disaster management in Madibeng is still in an infant stage.

As there is currently no scientific method of quantifying disaster risk and vulnerability levels in Madibeng, it is recommended that funds should be allocated to the designing and development of a fully functioning GIS that, in future, could facilitate proper decision making on disaster management.

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Appendix A

Madibeng Hazard Questionnaire.

May /June2002

nr_____

Name_____

Department_____

Interviewer_____

This questionnaire is part of the data capturing process for a Multi-Risk Hazard Assessment and Vulnerability Study of Madibeng Municipality, being carried out by Water Economics and Environmental Studies (Watees) and Netgroup Geosystems. Information gathered will be used in Geographical Information Systems to spatially indicate areas at risk of certain hazards.

Please indicate on the table below the hazards that are applicable to Madibeng Municipality.

Definitions

1. **Frequency:** Number of events per year. X if not applicable to Madibeng Municipality.
2. **Extent:** General area of impact rated from one to ten where 1 is a local impact (one stand / farm) and 10 would be a national disaster.
3. **Damage caused:** Historic value in Rand for damage caused by each hazard in a year if possible.
4. **Data :** Please tick if other data is available on identified hazards.

Please indicate general location of hazards on the attached map if possible by the number given in the hazard table.

#		1.	2.		3.		4.
Nr.	Hazard type	Frequency	Extent of Impact		Damage Caused		Data
			Direct	Indirect	Direct	Indirect	
	1. Chemical Hazards						
	Pollution related to:						
	1. Mines (specify)						
1.1a	-						
1.1b	-						
1.1c	-						
1.1d	-						
1.1e	-						
	2. Industry (specify)						
1.2a	-						
1.2b	-						
1.2c	-						
1.2d	-						
1.2e	-						
	3. Agriculture (specify)						
1.3a	-						
1.3b	-						
1.3c	-						
1.3d	-						
1.3e	-						

	2. Physical Hazards						
	1. Climatic						
2.1a	a)Floods						
2.1b	b) Hail						
2.1c	c) Wind						
2.1d	d) Drought						
2.2	2. Fire						
2.3	3. Earthquakes						
Nr.	Hazard type	Frequency	Extent of Impact		Damage Caused		Data
			Direct	Indirect	Direct	Indirect	
	3. Biological Hazards						
3.1	1. Deforestation						
3.2	2. Desertification						
	3. Intrusive / Problem:						
3.3a	a) Plants (specify)						
1	-						
2	-						
3	-						
4	-						
5	-						
3.3b	b)Animals (specify)						
1	-						
2	-						

3	-						
4	-						
	4. Dangerous:						
3.4a	a) Plants (specify)						
1	-						
2	-						
3	-						
4	-						
5	-						
3.4b	b) Animals (specify)						
1	-						
2	-						
3	-						
4	-						
5	-						
3.4c	c) Disease (specify)						
1	-						
2	-						
3	-						
4	-						
5	-						
	4. Cultural Hazards						
	1. Accidents :						
4.1a	a) Roads						
Nr.	Hazard type	Frequency	Extent of Impact		Damage Caused		Data
			Direct	Indirect	Direct	Indirect	
4.1a	b) Trains						
4.1c	c) Airplanes						

The following data will be needed in the study. Please indicate which of the data is available, the format in which it exists and the contact details of the person or department from where the data could be collected.

Data Requirements

Data	Availability	Format	Contact Details
Climate			
Rain			
Temperature			
Wind			
Humidity			
Thunder			
Hail			
Lightning			
Hydrology			
Runoff			
Floodlines			
Dams			
Soil type			
Landuse			
Landcover			

Infrastructure			
Demography			
Other			

Filename: Madibeng_multiple_hazard97.doc
Directory: C:\My_Documents\Projects\MSTOLS1\Tesis\Tesis\Hoofs
tukke\Nuut\Changes
Template: C:\Documents and Settings\Martin
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