DEVELOPMENT ACTORS AND THE ISSUES OF ACID MINE DRAINAGE IN THE VAAL RIVER SYSTEM

by

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ABSTRACT

This study focuses on Acid Mine Drainage (AMD) in the three basins of the Witwatersrand's goldfields in the Vaal River System in South Africa. AMD has become a highly contested issue. A difference in its definition exists between two groups of role-players identified in the study: government and consultants/activists/NGOs. This study unpacks the differences in the way AMD is defined, the situation of AMD in each of the three basins and the socio-economic implications caused by AMD. A crucial finding was that these definitions determine how the issue is understood and what solutions these role-players propose. The main purpose of the study was to determine whether the South African government's policy response was appropriate given the socio-economic impacts of AMD and imperatives of sustainable development. This study concluded that, in the policy, there was no clear indication as to what the socio-economic impacts are, and limited attention was therefore given to these impacts.

Keywords: ***Acid Mine Drainage, sustainable development, water management, mining, socio-economic impacts, South Africa***

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This dissertation is dedicated to my father, Preggy Naidoo, a man who had so many talents.

DECLARATION

I declare that *Development Actors and the issues of Acid Mine Drainage in the Vaal River System* is my own work and that all the sources that I have used or quoted have been indicated and acknowledged by means of complete references.

SIGNATURE
(Ms Suvania Naidoo)

DATE

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ABBREVIATIONS

ℓ	litre
µg	microgram
AMD	acid mine drainage
CANSA	Cancer Association of South Africa
CBD	central business district
CEO	Chief Executive Officer
CGS	[South African] Council for Geosciences
CSIR	Council for Scientific and Industrial Research
DEAT	Department of Environmental Affairs and Tourism
DME	Department of Minerals and Energy
DMR	Department of Mineral Resources
DMR	[Gauteng Provincial] Department of Mineral Resources
DRD	Durban Roodepoort Deep
DST	Department of Science and Technology
dti	Department of Trade and Industry
DWA	Department of Water Affairs
ECL	environmental critical level
EIA	environmental impact assessment
EMP	environmental management programme
ERPM	East Rand Proprietary Mines Ltd
FSE	Federation for a Sustainable Environment
GCIS	Government Communication and Information System
GDARD	Gauteng Department of Agriculture and Rural Development
GDP	gross domestic product
HDSM	high-density sludge management

IDC	interdepartmental committee
IMC	Inter-Ministerial Committee on Acid Mine Drainage
JSE	Johannesburg Stock Exchange
Mℓ	Million litres
MPRDA	Minerals and Petroleum Resources Development Act, 2002 (Act 28 of 2002)
MRA	mine residue area
NEMA	National Environmental Management Act, 1998 (Act 107of 1998)
NGO	non-governmental organisation
NNR	National Nuclear Regulator
NWA	National Water Act, 1998 (Act 36 of 1998)
NWRS	National Water Resource Strategy
PFM	platinum group metal
SAHTC	South African Human Rights Commission
TCTA	Trans-Caledon Tunnel Authority
TDF	tailings disposal facility
WCED	World Commission on Environment and Development
WMA	water management areas
WRC	Water Research Commission
WSCSA	Water Stewardship Council of Southern Africa

CHAPTER 1: INTRODUCTION

1.1 Overview and aim of the study

“Water is life. Both natural and human systems are critically dependent on water. It is the primary requirement for the survival of human beings, as also for their socio-economic development and healthy ecosystem” (Prasad 2003: xiii). This statement depicts the importance of water as a resource for human beings and the earth. It also indicates that any harm to our water system could negatively impact on human life, the earth and humankind’s aim towards a sustainable future.

According to section 24 of the Constitution of the Republic of South Africa, 1996 (Act 108 of 1996) (the Constitution):

> Everyone has the right –
>
> a) to an environment that is not harmful to their health and well-being; and
>
> b) to have the environment protected, for the benefit of present and future generations, through reasonable legislative and other measures that –
>
>   i) prevent pollution and ecological degradation
>
>   ii) promote conservation and
>
>   iii) secure ecologically sustainable development and use of natural resources while promoting justifiable economic and social development.

Therefore, any human activity that violates this right should be severely dealt with to ensure minimal harm to the environment and to people. Natural resources are vital for human beings’ existence and future life and, therefore, needs to be protected.

In South Africa water is regarded as a social, environmental and economic good. “Nevertheless, after basic human needs and the requirements for maintenance of ecosystems have been satisfied, there will inevitably be competition for access to the remaining available water” (DWAF 2008b: 12). Yet, “South Africa is a country that is bereft by a water security dilemma; whilst on the economic front, the country is driven by a strong mining industry” (Azarch 2011: n.p.). What is evident is that these two significant trends – water and mining - placed closely to each other have become increasingly unstable due to the increased inflow of “highly acidic water into the country’s water system” as a result of acid mine drainage (AMD) (Azarch 2011: n.p.). This has led to the endangerment of, and threats to, both communities and ecosystems along many water systems, including the Vaal and Limpopo rivers (Azarch 2011: n.p.).

This study concentrates on AMD as a phenomenon in water management in South Africa and what its impact on sustainable development is or could be. AMD is understood by different people in different ways, depending on their particular interests and institutional affiliation, such as to a government department, business, consultancy, and non-governmental organisation (NGO) or activist group. One category of interpretation of AMD refers to “highly acidic water, usually containing high concentrations of metals, sulphides and salts as a consequence of mining activities” (CSIR 2009: n.p.). The drainage from abandoned underground mine shafts seeps into surface water as the mine shafts fill with water. This is a narrower interpretation of AMD and concentrates only on underground water decanting from mine shafts. The other interpretation category extends the notion of AMD to include the phenomenon of acid rain as a catalyst for AMD originating from tailings dams. This form of AMD is a result of chemical interactions between acid rain and the dust formed on tailings dams or “mine dumps”. The mine dust on the tailings dams always includes radioactive particles (i.e. uranium) which exacerbate the AMD effect (Turton, personal interview, 2013).

The growing concerns that have surfaced, and are increasing on a daily basis, surrounding the issue of acid mine drainage are of the utmost importance and should be addressed more urgently. “Acid mine drainage [is] described as one of the most significant environmental threats facing South Africa, an already water scarce country” (*Mail & Guardian* 2011). This alone indicates the severity of these concerns and the need for action to be taken. “The problems posed by acid mine drainage will have implications far into the future, with impacts likely to continue for many years” (Reuters 2011). Water plays a vital role in the process towards a sustainable future; any harm that hinders this process should be looked into, and dealt with, immediately to mitigate the problem.

This study looks at the development actors who are involved in the issue of AMD, and investigates the uncertainty still present about how AMD is affecting socio-economic development. The role-players are many but the mining industry and government have the biggest roles as they are the parties responsible for the environmental crisis being experienced today. In Chapter 4 the responsibility of government and its policy approach in response to this environmental crisis are discussed in more detail. In 1886 immense gold resources were discovered in South Africa, especially on the Witwatersrand. This allowed the mining industry to play a central role in the country's economic, social and political environment (Adler, Claasen, Godfrey & Turton 2007: 34). The mining industry made it possible for the country to rapidly grow economically and this on its own secured government's support for the industry. The problem, however, stemmed from the fact that environmental harm and the severity of the impact of mining activities on several aspects of society were underplayed. Scholars therefore concluded that "in the process of development, mining is one of the core industries contributing towards the deterioration of the environment in terms of air, water and land pollution" (Tiwary, Dhakate, Ananda Rao & Singh 2005: 421). This has led to the current growing crisis encapsulated in the concept 'acid mine drainage'.

When discovered, the Witwatersrand basin of the goldfields had the world's largest gold reserves, and half of the gold that had ever been mined since 1886 came from these reserves. In 2002 the first incidences of AMD appeared on the West Rand near Krugersdorp in the Gauteng Province and, for the first time, raised serious concerns and awareness in the public domain about the effect of mining on the environment. AMD became increasingly prominent due to the ongoing debate, its growing media coverage, and the harm caused to the environment and scarce water resources. Despite greater exposure to this phenomenon, much of it was clouded in speculation, sensation and lack of clarity about its impact on society in general. Over time, more clarity emerged about its scientific (i.e. geo-scientific, chemical and engineering) characteristics, but the same cannot be said about its socio-economic impact. It is a challenge that this study is confronted with.

1.2 Problem statement and research questions

The potential consequences of AMD in respect of water quality, health hazards, policy challenges and sustainable mining have already been raised. A range of research problems can be identified in this context.

The first problem is the government's policy response to AMD. So far, such a policy is not yet fully developed and integrated, and consists of the South African Government's Inter-Ministerial Committee on Acid Mine Drainage's (IMC) (established in 2010 to coordinate government's response to AMD) expert report; the initial budget allocation in 2011 to arrest the problem on the East Rand in Gauteng Province; the decision to allocate AMD as a project to the Trans-Caledon Tunnel Authority (TCTA) (a state-owned specialised liability management body whose mission is to finance and implement bulk raw water infrastructure) in the Central basin of the goldfields; and attempts to improve preventative measures through better implementation of the Mineral and Petroleum Resources Development Act, 2002 (Act 28 of 2002) (MPRDA).

Policy decisions regarding who must take responsibility for the environmental impact of AMD are not yet finalised. Therefore, in 2011, the National Assembly's Portfolio Committee on Water and Environmental Affairs did not exclude legal action against mining companies (PMG 2011). In contrast, a company such as DRDGOLD (Durban Roodepoort Deep) Limited proposed a formula to determine proportional responsibility by the mining companies for AMD contamination. The implication was that the government must take responsibility for the remainder. None of these matters has reached the stage of a policy decision (PMG 2011). In South Africa - the African National Congress (ANC) - the ruling political party's latest policy discussion document on mining, "Maximising the Developmental Impact of the People's Mineral Assets: State Intervention in the Minerals Sector", dated 5 March 2012 (ANC 2012) also does not refer to AMD as a policy concern.

The policy dimension raises a number of issues, including the following:

- Given South Africa's general human development paradigm, how sensitive is this emerging AMD policy framework towards the demands and requirements of sustainable development?
- Is the primary focus of the emerging policy framework in the first instance a technical response or does it include a consciousness of the need to address the social effects of AMD in the context of sustainable development?
- As regards the possible value of it as a precedent for future similar situations, can this policy framework become an ideal example of how to approach policies that have to combine the pressures of economic development, environmental or ecosystemic sensitivity and human security?

The second problem is concerned with the social dynamics of AMD and its developmental impact. This study uses sustainable development as the prism through which the phenomenon is analysed. It attempts to determine the social impact of AMD on different actors in the Vaal River system in South Africa, which includes the catchments of the Upper, Middle and the Lower Vaal Water Management Areas (from Kuruman in the west to Ermelo in the east and Johannesburg in the north to the Lesotho border in the south) (DWAF n.d.). It is also important to determine whether there is a civil society response in the form of activist movements and media activism that emerged as a result of the increasing prominence of AMD. Which activities or aspects of the lives of those concerned are directly or indirectly affected by it? How do those affected respond to these effects? Are those involved in the government's attempt to articulate a policy response in the form of consultation or other forms of participation?

Guedes (2010: 69) and Adler et al. (2007: 34) elaborated on these social costs and how they relate to some of the actors. According to Guedes (2010: 69), an important point to acknowledge is that the mining industry believes that it cannot be held responsible for the consequences of derelict and ownerless mines. However, in the same breath, government also remains adamant in the belief that it cannot be held responsible for the clean-up that is needed due to the fact that it will cost billions of rand to do so (Guedes 2010: 69). The Chamber of Mines of South Africa (the Chamber of Mines) works closely with government and the affected mining companies to reach suitable solutions.

Combining the two stated research elements, the overarching research problem is, therefore, whether the evolving policy response and the social dynamics of AMD are sufficiently synchronised, and does this have the potential to find a way to deal with similar dilemmas in future, such as the proposed fracking in the Karoo and mineral explorations at Verlorenvlei in the Western Cape Province (in South Africa) or mining near Mapungubwe, a world heritage site, in Limpopo Province (in South Africa).

Based on the research challenges identified in the research problem, this study focuses on the objective to investigate and reach a conclusion on the following research question:

- From a sustainable development perspective, is the South African government's evolving policy response sufficiently synchronised or sensitive to the social dynamics of AMD in the Vaal River system?

From this research question it follows that the following are the research objectives of this study:

1. To determine and analyse the nature and content of the South African government's policy response to AMD. The study monitors how the policy evolved while the research was being conducted.

2. To determine the socio-economic implications of AMD in the Vaal River system. Who are affected by it and how are they affected?

3. To determine whether the emerging policy will be able to address the impact of AMD on society. If one approaches it from the perspective of sustainable development, is it sensitive to the elements that sustainable development

attempts to balance, namely economic development and growth, improvement of the human condition and respect for the environment?

1.3 Methodology

This section includes the research methods, tools, techniques, strategies and ethics that were used to conduct this study. A qualitative research design was used for the purpose of understanding and explaining a phenomenon. Ten key informants who are experts in this research area were identified and semi-structured interviews were conducted with each of them. Media and official policy documents were used to strengthen the validity and reliability of the arguments presented, and to compare them with the information found in the interviews. There were several limitations to the study. They are discussed in section 1.5.

1.3.1 Research design

This study followed a qualitative research approach. Qualitative research is used to "understand and also explain an argument, by using evidence from the data and from the literature, what the phenomenon or phenomena that we are studying are about" (Henning, van Rensburg & Smit 2004: 3–4). A qualitative approach allows for varying views of a theme being studied and in which the respondents have more open-ended ways of giving their views and demonstrating their actions. Thus, in qualitative enquiry, "the qualities, characteristics or the properties of a phenomenon are examined for a better understanding and explanation" (Henning et al 2004: 5). In the context of this study the focus is on understanding the dynamics of AMD in the Vaal River system, identifying and comparing what the various role-players are doing to address the situation, and to explain what effects these outcomes have on socio-economic development.

1.3.1.1 How the participants were selected

Some of the key informants who appeared often in the literature were identified as potential participants. Key informants are "those whose social positions in a research setting give them specialist knowledge about other people, processes or happenings that is more extensive, detailed or privileged than ordinary people and who are therefore particularly valuable sources of information to the researcher" (Payne & Payne 2004: 2). Key informants were of vital significance for this study, because they have expert knowledge on the subject and information that would be difficult to access otherwise. They were also familiar with the details of the issue regarding AMD, and what the current and future plans to address it are. The "key informants are different from ordinary informants to the extent that they have more information to impart and are more visible" and the reason for their visibility is because of their formal positions of authority (Payne & Payne 2004: 2).

When conducting the literature search, it transpired that several media reports often referred to or quoted the same government departments and spokespersons who commented on new developments with regard to AMD. Therefore, these spokespeople were identified as a crucial source of information for this study and were approached to be key informants. They were contacted and an interview was requested. The institutions concerned included the Cradle of Humankind World Heritage Site, Department of Water Affairs (DWA) and the Gauteng Provincial Department of Mineral Resources (DMR). During these interviews other key informants were recommended for their expert knowledge and relevant information to the study. This demonstrates the value of key informants in the sense that as a result of their position in society, they are very well informed about - and generally understand - the subject of the research, and their expertise is "to know who knows, so that [they] refer the research worker to others who are more knowledgeable than [themselves]" (Payne & Payne 2004: 3). The interviews conducted with the Department of Science and Technology (DST), Chamber of Mines of South Africa, AgriSA, and the activists Anthony Turton and Mariette Liefferink were found through so-called snowballing.

Snowball sampling was the main technique that was used to find the key informants. Snowball sampling is "finding research subjects where one subject gives the researcher the name of another who in turn provides the name of a third and so on" thus, the sample grows like a rolling snowball (Cohen & Arieli 2011: 424). Snowballing is known to be an effective method to gain access to hidden or hard-to-reach populations (Cohen & Arieli 2011: 427). In the present study the key informants were cautious about agreeing to be interviewed due to the highly contested and controversial nature of the AMD debate, and the fact that public exposure of it was seen as potentially damaging to the interests of the mining industry, both inside South Africa and also for foreign investors. Government regards mining as a strategically important sector and, therefore, too much public criticism or revelations of an embarrassing nature can become controversial. Anthony Turton's departure under pressure from the CSIR is a good example of such controversy. This made it more difficult to get key informants: some experts who were approached declined to be interviewed. Thus, through snowballing and referrals from one participant to another, the next informant in line was made more at ease about providing information and being interviewed. When the informant was approached, the researcher was able to say that it was through a referral, and this made that person more willing to participate in the study. Some of the key informants had sent the request to the other possible key informants to have an interview on behalf of the researcher but, in the end, all interviews were conducted by the researcher.

1.3.1.2 Qualitative research methods

Two types of data collection methods were used: official documents and semi-structured interviews.

The use of official documents was crucial to this study. A qualitative content analysis of the documents was done to determine the use of each of the documents found to be suitable for this research topic. These documents were publicly available, including the ones that were provided by the informants during the interviews. The use of these documents served as a vital source of information as questions that were asked in the interviews were to clarify or confirm the information in these documents. The use of these documents also assisted in finding gaps in the research on AMD which is discussed in chapter 4 and 5.

Semi-structured interviews were conducted with the key informants. The questions asked in these interviews, therefore, differed for the various key informants. Each of the key informants was from a different field, and had different information and expert knowledge about AMD. Accordingly, the interviews had to be structured in line with their expertise and focus areas. Even though there were set questions for the respondents, new questions arose during the interviews based on their responses, views and the new information that they provided.

The nature of the topic made it necessary to interview role-players that were representatives of government (i.e. DWA, DST, and the Gauteng provincial Department of Mineral Resources), the private sector (i.e. Chamber of Mines); activists and NGOs (i.e. Anthony Turton and Mariette Liefferink from the Federation for a Sustainable Environment); and then sectors that affect tourism (i.e. Cradle of Humankind); and the main consumer of water, which is agriculture (i.e. AgriSA). Each of these sectors was crucial to the study as the information that they provided allowed for better analysis and more reliable conclusions.

Stephinah Mudau, Head of the Environment Sector at the Chamber of Mines, is an expert in mining policies, and was able to provide her views on the mining industry and their role in the AMD debate. Thus, the questions she was asked were focused on the mining industry and its impact on the environment. She was also asked about the existing legislative framework and possible better approaches to ensure that AMD was prevented in future.

Peter Kelly from the Gauteng provincial Department of Mineral Resources (DMR) was also able to provide information on the mining industry and those mining companies that were directly related to the problem. He was well acquainted with the technical aspects of the manifestation of AMD in each of the three basins and the work being done there. He stressed the fact that the information he provided was entirely his own views. However, what made the interview with Kelly so important was that he was part of the DMR processes addressing AMD in Gauteng. His views were, therefore, based on what he observed first-hand by dealing and working daily with this issue. His own views provided the researcher with a much better understanding of the issues involved because of his proximity to the real issues.

Bashan Govender, Deputy Director from the DWA, was significant for this study, because DWA is at the centre of addressing the AMD issues and management of water resources in general. The purpose of the interview was also to clarify the impact of AMD and what the DWA was doing to ensure that the country's water resources and the environment were not further harmed. The questions posed to Govender were partly based on the media reports that had criticised the department for its lack of commitment in addressing AMD and partly on the literature regarding the effects of AMD. Govender was able to explain and to provide alternative information on how the issues were being addressed, and what treatment strategies were being used in the three river basins.

The Department of Science and Technology (DST) plays an important role in advising on the process of searching for long-term solutions to AMD. Shanna Nienaber is the Deputy Director of Environment Services sector at DST. She previously worked with the CSIR, comes from a social sciences background and is working with many of the role-players (i.e. government, NGOs, communities and scientists) in the field. She was able to provide an overall view on AMD, why the problem existed, what was being done and what still needed to be done. She played a vital role in the study as she was able to provide important views on what the socio-economic impact of AMD was and also referred the researcher to other people in the field.

Peter Mills, the Deputy Director of Integrated Environment and Conservation Management at the Cradle of Humankind World Heritage Site, provided an overview of his knowledge on AMD, more specifically in the Western basin and the Cradle of Humankind as a tourist attraction. The questions he was asked explored the possible impact of AMD on the archaeological wealth of the Cradle of Humankind and on tourism in the area. The area is also used for farming and, therefore, the socio-economic impact of AMD in this regard was included in the discussion. He provided several documents that were already available to the public on what was being done in the Western basin.

Mariette Liefferink, the Chief Executive Officer (CEO) of an NGO called the 'Federation for a Sustainable Environment', took the researcher on a field visit to the West Rand. She showed and explained the areas that were affected by decanting due to AMD and discussed AMD from an activist approach. Her views were entirely different from those of the other interviewees as she was strongly focused on the people aspect and what AMD does to communities and the environment.

Activist Anthony Turton, who previously worked for the CSIR and is now an environmental advisor, speaker and author from Touchstone Resources provided essential information and an extremely insightful overview of AMD. He presented a neutral view and was more concerned with what could be done and what was being done, rather than attributing blame to any role-player. He was questioned on how he defined AMD, his overall views on the severity of the issue and on its socio-economic impact. Turton provided information that was entirely new and that opened doors to a different way of looking at AMD.

Three representatives of the national agricultural union, AgriSA, namely Nic Opperman, Adriaan Louw and Meiring du Plessis were interviewed. The interview focused on how agriculture could be affected by AMD, cognisant of the fact that this sector was the biggest consumer of water in South Africa. AgriSA was asked whether or not it already had evidence of negative factors of AMD, and what the negative impact on farming and crop production might be in future. AgriSA provided a document that included case studies of the incidences on farms that affected farming activities. These case studies are useful illustrations of the socio-economic impacts that AMD has.

When conducting the interviews, each informant was asked for their permission to use a tape recorder. All the respondents agreed. This was extremely useful for the research as it allowed for more time to engage and understand what the informant was saying instead of focusing on taking notes. It was also useful to have the interview recorded instead of just taking notes to avoid misunderstanding or misinterpreting information. The recordings were then transcribed and the necessary information was used. The interview with Mariette Liefferink was combined with a field visit to some of the sites on the West Rand that were affected due to AMD and this provided a useful illustration of the actual impacts of AMD.

In each of the interviews, informants were asked what their views were on the government’s IMC expert report and on whether AMD could have an impact on socio-economic development as this was crucial to the study. This is discussed in detail in Chapter 5.

1.4 Ethical considerations

Every research project must take ethical considerations into account. Ethics is associated with morality and it deals with matters of right and wrong, "conforming to the standards of conduct of a given profession or group" (Babbie 2011: 478). In this research study the participants that were interviewed hold a high rank in their professional fields and due to the fact that this topic has gained much media attention, it was essential that the participants be asked for their consent before using their information.

When first requesting interviews with the key informants, the nature and purpose of the research topic was explained. At the start of the interview with each key informant their permission was asked for a recorder to be used. The nature of the research was explained and how their information would be used. Participants were told that all information that they provided during the interview would be used for academic purposes and not for public use in the media as this topic was one that was highly contested and often received negative media responses. After the interview interviewees were contacted to confirm their consent in writing.

Anonymity and confidentiality are crucial aspects to take into account when conducting research especially with information that is sensitive. The respondents were asked if their names could be used in the study and all indicated that their names and their professional designations could be used in the research. One key informant mentioned that he was not speaking on behalf of his department and references should therefore be made to him and not his department. To avoid any misinterpretation, all the references in this study refer to the interviewees and *their* views and not to those of their institutions.

1.5 Limitations of the research

Most of the research and literature available on AMD is of a technical-scientific nature. Given the fact that this is a study in Development Studies, the first limitation was that the focus of this research was from a sustainable developmental social perspective on the socio-economic dimensions of AMD and not the technical-scientific issues. Some of the key informants also concentrated mainly on the technical aspects of AMD and the researcher's task was to extract the socio-economic dimensions from it. Therefore, in the discussions the technical aspects were limited to the minimum and presented in a simplified manner relevant to a social scientist.

A second limitation was that the researcher depended on the views of the key informants (i.e. the stakeholders, NGOs, experts and consultants) and did not conduct an independent scientific field investigation, which would entail going to the rivers and the actual sites of decant or the sites where pumping was taking place to conduct tests personally about the water quality, radioactivity or dust pollution. Instead, existing scientific studies and interview responses were relied upon, combined with the researcher's field visit to the West Rand with activist Mariette Liefferink and then conclusions were drawn. Even though this one field visit provided a practical understanding of what the situation looks like, the researcher depended largely on Liefferink's assistance in this regard. Therefore, in order to identify the empirical aspects of the socio-economic impacts the views of the experts in the field were relied upon. The researcher's own interpretation was based on a combination of these empirical aspects and knowledge of sustainable development as a discipline.

The last limitation related to the use of confidential documentation. Some of the key informants provided documents that had not yet been published but had been discussed among the most notable role-players in the field and contained essential and relevant information that could be used in this study. Due to ethical considerations and the confidentiality element, restrictions applicable to the documents had to be adhered to and, therefore, no direct reference could be made to this information, even though it provided a better understanding of the issues surrounding AMD.

1.6 Outline of the study

This section provides a brief overview of what the chapters in the study entail. Chapter 2 is an overview of the existing literature on the topic. The theoretical framework is clarified by discussing how public policy within sustainable development is used as the framework for this study. The key concepts, including AMD and sustainable development, are defined. The importance of water and its place in sustainable development are discussed.

In Chapter 3 the nature of AMD as a concept is discussed. The current state of the phenomenon in the three basins of the Vaal River system is presented as a means of developing an understanding of the scope of AMD in the Witwatersrand and the resultant challenge facing the policy-makers to find a sustainable solution for AMD.

Chapter 4 discusses the policy response to AMD in the gold mining sector. It discusses the government's policies and processes on addressing AMD, including the IMC's expert report. The chapter also considers the role that NGOs and activists have played in in this regard.

Chapter 5 looks at the socio-economic impact of AMD on different sectors of society. The chapter explains the impact that AMD has had or can have in future on the environment and human beings, and what the possible solutions are.

Chapter 6 concludes the study and presents the main points and arguments that emerged from the research.

CHAPTER 2: A REVIEW OF THE EXISTING LITERATURE ON ACID MINE DRAINAGE IN SOUTH AFRICA

2.1 Introduction

The objective of this chapter is to conduct a brief evaluation of some of the published literature available on the topic of this study. Therefore, this chapter presents a limited review of the existing information that is available on AMD. At the same time, the theoretical focus of this study will also be developed. The intention is to inform readers of the existing research and the reporting that has been done so that they can understand the broader context in which this topic is located and the current state of knowledge on the topic. The implication is that the discussion also identifies areas in which further research is required.

The literature review is structured in such a way that it addresses some of the main fields and concepts relevant to this study. The two key elements of the research topic are (1) water and (2) sustainable development, and from these, related elements are derived. Sustainable development on its own is both a complex phenomenon and an ever-expanding sub-discipline within Development Studies. For the purpose of this study it is not feasible to conduct a literature review on all its manifestations. Rather, the relevance of water for sustainable development is the focus. Given the nature of the research topic, the concept of water will be confined to sustainable water management and consumption in South Africa, and more specifically in Gauteng and the Vaal River system.

Another element of the research topic is the impact of mining on water quality and, by implication, its impact on sustainable development. For this reason, a brief literature review of mining (and, more specifically, gold mining) was conducted. A brief summary of the significance of the mining industry in South Africa and the negative impacts of the mining industry is provided. This brings one to the specific focus of this study, and that is to review the literature on AMD in South Africa. Almost all the provinces in South Africa are likely to be effected by AMD, except for the Western and the Eastern Cape. Gauteng Province remains among the most affected areas where “the AMD sources sat atop the continental watershed, the waters of which ultimately drained into the Vaal, Orange and Limpopo rivers" (Esterhuizen 2012b). The three main areas in Gauteng are the Western, Central and Eastern basins of the Witwatersrand which have seen considerable decant (decant is an overflow of underground mine water at the surface) but mainly in the Western basin (Esterhuizen 2012a). It should be reiterated that the focus of this research is not from a technical perspective, which includes the engineering, mining, geological and related aspects of the issue, but on its social and developmental significance.

In addition to the different components of the topic, the different types of publications and sources in which the information is available are identified. The first type is published academic research literature, especially in the form of journal articles, book chapters and conference proceedings. Second, the issue of AMD receives increasing attention in the media. Thus, identifying how the issue is presented by the media is essential. Third, is legislation, policy documents and official reports published by the departments involved and other authorities.

The purpose of this chapter is not to discuss substantially the issues related to AMD, but rather to identify trends in the research, thematic focus areas and different approaches in the literature. Substantive discussions will follow in the specific chapters hereafter.

In the following sections attention is paid to specific facets of the literature review.
What tends to be common in most of the literature on the topic is that mining activities are vital for economic growth. However, once operations have ceased, the problem arises for various reasons, which are mentioned later in this chapter. The main questions still remain, which are: What will be done after the harm from human activities has negatively impacted on the environment and how are these issues going to be addressed? With regard to the numerous areas being affected, how can the problems that AMD has caused to the environment and the negative impacts that the mining industry brings with it be managed and hopefully prevented?

2.2 Understanding the key concepts

In this section the key concepts, including AMD and sustainable development, that are used in this study are defined or conceptualised. At the same time, explanation of the key concepts as they are presented in the existing literature serves the purpose of setting out the key elements of the theoretical framework of this study.

2.2.1 Acid mine drainage

Acid mine drainage has commonly been described as “the single most significant threat to the environment” (Ochieng, Seanego, & Nkwonta 2010: 3352). In the existing literature it is defined as “acid water that is formed underground when old mine shafts fill up with water, which oxidises with the sulphide mineral iron pyrite. It can then decant into the environment causing acid mine drainage” (Guedes 2010: 67). AMD can be formed from coal and gold mining, both in surface and underground mines (Leonardi 2011: 2). Another definition is that AMD is “highly acidic water, usually containing high concentrations of metals, sulphides, and salts as a consequence of mining activity” (CSIR 2009: n.p.). There is a tendency for the concept to be defined in a rather technical manner. However, for the purpose of this study the focus has to be from a social perspective. The following conceptualisations of AMD in the existing literature could therefore be useful for this study:

According to Cobbing (2008: 452),

> corrosion of sulphide minerals in the presence of water can generate large amounts of acidity. When mine operations stop, dewatering pumps may be turned off and water levels start to return to their natural level, this process is known as “rebound”. The water comes into contact with rock that contains sulphide minerals that have been exposed through mining activities and the pH of the water may drop considerably due to the resulting chemical reactions. This acidic water could dissolve into other minerals in the rock, which can lead to high concentrations of pollutants such as lead, zinc, aluminium or cadmium in the water and high salinity generally. The polluted acidic mine water may then overflow at the ground surface and at times in

> enormous quantities which results in the problem known as ‘Acid Mine Drainage.

According to the South African government’s IMC (Coetzee, Hobbs, Burgess, Thomas & Keet 2010: 4), acid mine drainage has a seriously significant as well as costly environmental impact on the mining industry worldwide. When AMD is formed due to the closure or abandonment of mines, it affects surface and groundwater.

In Chapter 3, definitions or descriptions of AMD are discussed, and a more detailed analysis of the phenomenon will be presented based on the research conducted for this study, mainly in the form of interviews. The different definitions or interpretations of the concept will then become clear.

2.2.2 Sustainable development as a concept for this study

The overarching concept used in this study is sustainable development. Given its prominence in Development Studies as a discipline, it serves, at the same time, as the overarching theoretical framework of this study. The other elements of the framework will be mentioned later. The theoretical point of departure of this study is that an investigation into the socio-economic impacts of AMD should be located within the framework of sustainable development. It determines the parameters and criteria for identifying what should be investigated, who should be investigated and how the relationship between human activity and the environment should be approached. Sustainable development is a “dynamic concept”, it is a term that is of the utmost importance to human beings and the environment (United Nations 2008: 20). In this section the concept ‘sustainable development’ is explained in the way that it will apply to this study and the intention is not to provide a comprehensive literature review of all its aspects and manifestations. ‘Development’ is its foundational concept and for the purpose of this study it will not be discussed further. It is presumed that it is such a broad discipline in its own right, developed by so many scholars that no justice would be done to try to capture all its nuances here.

In the literature review it appears that development and human well-being tend to be vital concepts when defining sustainable development. However, it is insufficient to limit sustainable development to this (United Nations 2008: 20). The first principle of conservation is development, stating that sustainable development depends on good environmental management and in turn good environmental management depends on sustainable development" (RSA 1997: n.p.).

"When the Rio Earth Summit convened in 1992, the world came of age. The decision to promote sustainable development was a defining moment in the history of social progress, peace and development" (RSA 1997: n.p.). This in itself explains the significance and relevance of promoting and aiming for a sustainable future. In 1987 the World Commission on Environment and Development (WCED) (in United Nations 2008: 18) defined 'sustainable development' as "development that meets the needs of the present without compromising the ability of future generations to meet their own needs". This definition means that the earth's resources should be used in such a way that these resources are preserved for future generations. Thus, the process of sustainable development aims for development that is continuous and that increases the well-being of life over a long period (United Nations 2008: 20).

The overall objective of sustainable development is to increase the well-being of an ecosystem (i.e. humans and the natural environment) over time; it is a development path that can be continued over a very long period (United Nations 2008: 20). According to the United Nations (2008: 20), "simply being sustainable does not make a development path desirable. It also matters whether it is the sort of development path that society wants to follow and this depends on what determines well-being for its members".

Thus, sustainable development is to ensure both the well-being of those currently living and the potential for the well-being of future generations (United Nations 2008: 21). This represents an integrated view. According to this integrated view,

> A framework for measuring sustainable development must be able to illustrate – in a perspective of both time and space – whether and for whom freedom to pursue well-being is increasing or declining, how access to and appropriation of resources are distributed, how the negative effects of resource use are distributed and to what extent resources are used in a responsible manner

> with regard to meeting current and future needs. This is the measurement of sustainable development and must focus on both the options of the current generation and on the prospects for those yet to come (United Nations 2008: 20).

Also mentioned in the United Nations report (2008: 22) is that if the present needs are met, the poorest people in the world will be affected. Disparity between rich and poor will decrease as societies have preferences regarding equity among their own members, and between themselves and other societies. Thus, the way resources are distributed will, in fact, have an effect on current well-being. According to the Government Communication and Information System (GCIS) (2010: 366), with the large mineral reserves in South Africa, it is evident that the mining industry also plays a big role in “the war” against poverty and underdevelopment in South Africa. Thus, the industry will have a negative impact in striving toward a sustainable future and preserving the earth’s resources.

The existing literature presents sustainable development as a visionary development paradigm. Over the past 20 years governments, businesses and civil society have accepted sustainable development as a guiding principle (IISD 2010: 5). However, not much has been implemented. Thus, unsustainable trends are continuing. Sustainable development embodies integration and understanding, and acting on the complex interactions that exist between the environment, economy and society (IISD 2010: 6). The interdependence of these three pillars must be acknowledged. Sustainable development as a process is vital and the following statement shows why: the alternative would be “accelerating deterioration of the human environment and natural resources and the consequences of that deterioration for economic and social development” (IISD 2010: 7). This statement also represents the reason why the WCED was created to address this very issue. It is vital to “enhance growth with care for the environment” (IISD 2010: 10). The main view of governments and businesses is that sustainable development is “continued economic growth made more environmentally sensitive in order to raise living standards globally and break the link between poverty and environmental degradation” (IISD 2010: 10).

If critics tend to believe that sustainable development will be difficult to achieve, and will take immense time and effort, then the aims and visions that humankind has for obtaining a sustainable future may not be reached. The continuous crisis and harm to the environment (including in the form of AMD) is only worsening the environmental crisis. Therefore, the questions raised in the literature are how will the lives of the poor be improved if sustainable development remains unsuccessful, and how will the three pillars of (1) economic development, (2) social equity and (3) environmental protection be addressed (IISD 2010: 12)?

Another factor raised in the literature that will require consideration in the path to ensure that the process of sustainable development is successful is the increased population growth. It means "humanity's demands on the planet have increased over the last 45 years. Thus, provision of many critical ecosystem services (water, biodiversity, fibre and food) will be compromised due to the impact of human development" (IISD 2010: 15).

The aim and goals of sustainable development will definitely become difficult to obtain if the challenges that the environment faces are not reduced and eventually eliminated. For the purpose of this study, the issues that AMD has brought about, and its contribution to environmental degradation and the human element are examined.

2.3 Water and Sustainable Development

The second element that this study develops in its theoretical framework is the role that water plays in sustainable development. This study assumes that water is not merely one of the many elements of an ecosystem, but plays a quite specific role in most development processes. As part of this role it is theoretically assumed in this study that the clean water appropriate for human consumption, industrial development, agricultural production and other usages is an absolute requirement for any form of development. The absence of such quality water, either where there is a water shortage or in the form of contaminated water, will be detrimental for development in general. At the same time, water is also a key element of the natural environment and most ecosystems. Development in general often has a detrimental impact on the natural quality of water and, therefore, on environmental sustainability. As a result, from a conceptual or theoretical point of view, this study assumes in a theoretical, systems approach that water plays a dual role: (1) it is a key "input" factor and an essential requirement for almost any form of development, and (2) on the "output" side, very often it is directly affected as part of the natural environment by the implementation of development and its impact on the natural environment. Given the mobility and fluidity of water, any negative impact on it cannot be contained within a specific location. Therefore, in terms of systemic "output", water as a medium extends the potential negative impact much further than the place of origin. In this study AMD is approached from this point of view. On the basis of existing literature, the relationship between sustainable development and water is developed further in the sections that follow.

2.3.1 Why clean water is so important?

The existing literature indicates that clean water is vitally important, first and foremost, because it is "essential for survival and growth of human beings and natural systems" (Prasad 2003: 1). "Access to clean water is universally accepted to be a precondition for economic and social development" (Oelofse, Hobbs, Rascher, & Cobbing 2007: 4). According to the South African Department of Trade and Industry (dti) (2013: n.p.), "water is a critical element to sustainable socio-economic development and the eradication of poverty". Water is also a vital resource for drinking, household use and food production. Thus, water is vital to continue with daily human activities, such as irrigation, bathing, washing, cleaning, cooling and processing (Hoekstra, Chapagain, Aldaya & Mekonnen 2011: 1). Fresh water is becoming scarce and the competition for it is increasing, which is of concern to many regions in the world, with almost 50 countries facing severe water stress (WWF 2008: 2). "Agriculture, industry, household distribution and consumption to the production of hydroelectric power and the maintenance of recreational areas, the activities and bodies that intervene directly in the use of the water resources available are many" (Cravidao & Mateus 2003: 36). Therefore, a proper well-designed management system is necessary to minimise natural conflicts, and to establish rules and priorities among users of the resource.

If the effects of AMD are not reduced, controlled and eventually eradicated, the negative impact and extensive harm that it will bring to South Africa's water system will be immense, and will eventually collide with human beings' daily uses of water that are necessary for survival and will severely hinder the process of sustainable development.

"South Africa has limited water resources and is regarded as the 30th most water scarce country in the world" (dti 2013: n.p.). Water thus plays a "critical function" in the South African economy, because about 60 per cent of the total national water usage is absorbed by agriculture and irrigation (dti 2013: n.p.). "While global resource availability is likely to keep pace with increased general consumption, frequent local and regional shortage will continue to threaten our existence and challenge present governance and management systems" (RSA 1997: n.p.). Thus, water usage must be addressed and the means of obtaining water must be guaranteed and not be put at risk (e.g. in the form of AMD). Since 1994, the democratisation of South Africa has allowed for a decrease in disparities between the different sectors of the South African society with regard to access to resources whereby water remains essential. One also finds that the increase in exploitation of water resources to meet the increasing demands in South African catchments and the "intensification of associated impacts on water quality need to be addressed" (Mukheibir & Sparks 2003: 5). Constant awareness of the importance of water for the daily survival of human beings and also for commercial businesses that can lead to growth in the economy is essential.

2.3.2 The importance of water for sustainable development

Once the importance of water in general has been demonstrated, the question arises: How does the existing literature integrate it with sustainable development? Water is used for consumption, yet human activities pollute vast volumes of water (Hoekstra et al. 2011: 1). For sustainable development to be successful, the risk to this resource needs to be limited. Water resources will always "influence the activities of mankind and the economic and social advancement of communities" (Cravidao & Mateus 2003: 36). Therefore, in order for the resource to be sustainable, "analysis, planning and management of water resources must thus be viewed as an integrated whole in accordance with the cultural and economic progress of the society" (Cravidao & Mateus 2003: 36).

It is widely known that the availability of South Africa's freshwater resources are being used to its full potential and is already under stress of being exhausted (Department of Agriculture 2008: 8). "South Africa's economy is highly dependent on natural resources for food and energy production. To achieve sustainable development, it must be recognized that the economy and the environment are co-dependent, i.e. that economic instability leads to environmental degradation, and responsible environmental management makes economic sense" (Department of Agriculture 2008: 8).

Billions of people suffer because of lack of clean water (Martin-Osuagwa 2010: 12). Some 2.5 billion people around the world live in communities that lack proper sanitation (Martin-Osuagwa 2010: 12). This can lead to the contamination of water used for drinking, bathing and washing clothes (Martin-Osuagwa 2010: 13). How to manage water is said to be "one of the greatest challenges of the 21st century" (Cravidoa & Mateus 2003: 36).

According to Cravidao and Mateus (2003: 36),

> Today, water is a world heritage, and, as with other types of heritage, it has to be governed by an international culture. Because of scarcity, because of local conflicts it causes, because of its importance to public health worldwide, because of the environmental requalification and valorisation that it promotes and also because of its symbolic value. Thus, it's a resource and a risk.

This means that many countries throughout the world stand the chance of facing severe water shortages which will mostly affect the poor, as it becomes even more difficult for them to meet their basic needs.

The Witwatersrand metropolitan area in South Africa (which potentially can be affected by AMD) has a population of 11 million people. The area is increasingly dominated by Johannesburg, and many satellite towns and cities spawned by the gold mining activities of the last century. It is said to be one of the largest concentrations of humans that has developed away from a sustainable water resource. Therefore, the history of the water issue in Johannesburg is the story of Rand Water, which is also based in sustaining a major urban conurbation that is far greater than the actual limits of this city alone (Turton, Schultz, Buckle, Kgomongoe, Malungani, & Drackner 2006: 314).

2.3.3 What are the developmental implications of contaminated water in South Africa?

The literature on water issues in South Africa is in most instances still speculative about the possible social implications of compromised water resources. According to Adler et al. (2007: 37) without access to clean water there could be social unrest and civil war in the country. There could be racial tension, and the failure of government to provide clean water could result in violent public acts and disputes which could, overall, lead to immense conflict in the country. In February 2014 such outbursts of community demonstrations about water supply took place in Brits in the North West Province (Stone 2014).

“Water resources management in South Africa has changed from the old riparian scheme based on landownership to a system which recognises water as a common resource, with the state acting as a trustee” (Cobbing 2008: 453). In line with the definition of sustainable development, “the basic needs of people followed by the allocation of sufficient water to sustain the environment, takes priority over other uses of water” (Cobbing 2008: 453).

The National Environmental Management Act (Act no 107 of 1998) (NEMA) and the MPRDA have laid down new obligations for the mining and other industries, which include the requirement to monitor and remediate pollution of water resources (RSA 1998b; RSA 2002). Modern South African law in general also recognises that rehabilitative management of mines needs to continue after extractive operations have ended and that planning for the mine closure phase should always be in place.

In the past, the ways in which mine pollution has been managed in South Africa was not adequate and the continuous water problems are often due to the ongoing mining activities. However, the most serious water quality problems may only occur once the dewatering (i.e. pumping) by the mining companies ceases and the mines are closed.

2.4 The Significance of the Mining Industry

2.4.1 The history of mining and mining rights in South Africa

Extensive literature exists on mining in South Africa (Handley 2004; Pogue 2006; Adler et al. 2007; Viljoen 2009; Tang & Watkins 2011). The latest book that appeared is by Jade Davenport, (a journalist for mining weekly) titled *Digging deep: A history of mining in South Africa* (Davenport 2013). For the present study, a choice had to be made from this literature, which meant that the discussion is not presented as necessarily a scientific representative sample of all the views in the literature. The history of mining is included here primarily to provide a context and historical perspective in order to understand the specific issues of AMD. The background information below has been taken from a publication by Adler, Claasen, Godfrey and Turton (2007), titled *Water, mining and waste: An historical and economic perspective on conflict management in South Africa.* This publication provides a detailed and insightful understanding of the history of mining, its importance and aspects associated with the mining industry in South Africa.

According to the South African Government's IMC (Coetzee et al. 2010), South Africa's mining history has generated immense economic benefits and continues to play a crucial role in ensuring the country's position in the global market. However, these resources can also be problematic. "Africa's variable and unreliable resources have contributed to numerous conflicts predominantly water, agriculture and livestock" (Adler et al. 2007: 33). Since the 1880s in South Africa such conflicts have arisen from European settlers' access to mineral resources which increased the problems in the water sector. The government policies during the apartheid era favoured the mining industry at the expense of the masses. As a result, since South African democratisation in 1994 it has been difficult to uphold citizens' new constitutional rights of equal access to water and other natural resources. If citizens continue to remain without drinkable water while the mining industry continues to visibly pollute the water without consequences, then government risks losing its legitimacy.

In order to understand the current problems (such as AMD) associated with the mining industry, one needs to understand South Africa's past. This is essential to developing a better policy and solutions to address the conflict with mining that has arisen and, ultimately, to ensure that citizens have access to potable water in the long term.

In 1886 "immense gold resources" were discovered in South Africa, especially in the Witwatersrand, and the mining industry played a central role in the country's economic, social and political environment (Adler et al. 2007: 34). Since then, "Johannesburg has grown from a dusty mining town to a major urban and industrial conurbation that houses and sustains a quarter of the total population of South Africa, accounting for 10 per cent of economic activity on the entire African continent" (Turton et al. 2006: 313). South Africa's minerals are highly diversified, profitable and plentiful, and this led to government giving the industry the benefit of the doubt by allowing it to maximise its profits and externalise costs.

In the early days the gold economy was an extractive industry not based on the notion of sustainability and, thus, there were no considerations about its possible long-term effects. This was substantiated and supported by water policies that "classified water used by the mines separately from water used by other industries, the mining-based economy developed in the Far West Rand which held the largest gold deposit in the world" (Adler et al. 2007: 34). However, these deposits made extraction technically complex and physically dangerous (due to dolomite aquifers) and therefore, "to extract the maximum amount of gold the industry employed an elaborate pumping system to draw groundwater from the sunken shafts" (Adler et al 2007: 34). The consequences of this included compromised ground stability, which also caused the groundwater to be exposed to pyrite and other minerals, which had an adverse impact on quality through acidification and subsequent heavy metal contamination.

Complaints from farmers already began to surface in 1905 but not much was done by government until 1956 when an interdepartmental committee (IDC) was established to investigate the effects of mine dewatering practices and their termination in most instances. The long-term consequence of dewatering the mines was that the value of the additional gold production over a period of 60 years was at least 3.5 times more than if the mines were not dewatered. However, sufficient mine closure plans were not developed and regulatory measures were considered "amicable agreements" rather than new and enforceable legislation. Government continued to profit from the industry by collecting approximately 57 per cent of all mining profits in the form of taxes and levies (Adler et al 2007: 34). Government allowed entrepreneurial and profit interests of large mining houses to merge with that of the state. Government was expected to act on behalf of its citizens to set standards to regulate the industry and to ensure that those standards were adhered to but instead "government allowed its definition of mineral ownership, based on Roman-Dutch common law to justify its passive position toward the industry in support of an unsustainable, yet highly lucrative extractive process" (Adler et al. 2007: 35). Through this, the government allowed the mining industry to gain control.

One of the best-known social science experts in the field of South African mining and AMD, Anthony Turton, is of the opinion that AMD should be understood in terms of the historical evolution of the government's policy towards mining. He states that the crucial problem is that the existing mining policy reflects a historical legacy in which powerful financial interests coincided with the interests of a racially-defined political elite, which saw government becoming an agent rather than a controller of the mining industry (Turton, personal interview, 2013). He explains how as a commercial entity gold mining had its origins in the Anglo-Boer War (1899–1902), the main purpose of which was to capture the South African mineral resources for the benefit of the British Empire. He identified the following four historic phases in the historical development of mining, which are essential to understand in order to find a solid solution for AMD:

1886–1902: The pre-industrial phase of mining

This phase of mining was characterised by low levels of technology and capital, developing at this time an ill-defined resource (Turton, personal interview, 2013). The mining operations were mostly of a narrow nature with inadequate underground development away from the surface outcrops of the Main Reef. The Anglo-Boer War allowed for changes in terms of which the consolidation of all gold resources came under sovereign British control.

1902–1961: The industrial phase of mining

This phase was generated by the initial sovereign control over the resources by the British, which allowed the consolidation of the many small leases into units that could be more profitably developed by means of deep-level and capital-intensive mining. Rand Water Board was given the responsibility of developing water resources for the exploitation of the goldfields, of which gold mining companies had formal representation. In the Western and Far Western basins, the depth of these mine workings was initially limited by the existence of a massive dolomitic aquifer that extends in compartmented form, from the East Rand in Gauteng Province, in a crescent south of Johannesburg, to the West Rand also in Gauteng Province (Turton personal interview, 2013).

1961–1994: The deep-level phase of mining

This phase was characterised by dewatering of the dolomites in the Western and Far Western basins, authorised by a formal commission of inquiry that began its work before independence from Britain. The committee's work was rushed by the transition of South Africa to the status of a pariah state: arising from the Sharpeville Massacre (1960) and the severing of ties with the British Commonwealth (1961). This brought about a very rich period of gold extraction during which profits were maximised by externalising costs. In this phase the mining industry became a strategic partner with the state, continuing the policy of apartheid while making significant profits "via the externalisation of [a] costs model sanctioned by the regulatory authority" (Turton, personal interview, 2013).

1994–present

This phase of mining is characterised by the advent of democracy. It overlapped with the gradual scaling down of mining operations as the economics of old mines approaching the end of their useful lives became marginal due to a low gold price in real terms and falling recovered grades. Ownership of mines had passed to smaller entities and in this time deep-level mining operations spiralled down, together with cessation of the pumping of water in the Western basin in 1996 (Turton, personal interview, 2013).

With the transition to democracy in 1994, the philosophy regarding ownership of natural resources also changed. In the past, the landowner had first right and access to the water and mineral resources that were on the land. However, with the new constitution and the MPRDA (RSA 2002) this form of ownership changed. “Natural resources have now become the people’s collective property, with government acting as a custodian” (Adler et al. 2007: 34). It means that the ‘old generation rights’ of private ownership had to be converted into ‘new generation rights’ granted as permits by the Department of Mineral Resources for a specified period. It amounted to a form of ‘nationalisation’ of mineral (as well as water) rights.

Due to the fact that government and the mining industry had developed a history of co-operation over the years, as well as the understanding that the economic model supported this interaction, allows one to identify the weaknesses that exist, and recognise the critical need for new, strong and coherent legislation.

The discussion of the literature in this section highlighted the relationship between the mining sector and government, and suggested that the government’s policies over time are an important factor to be included in one’s understanding of mine water management, including AMD. In Chapter 4, the government’s response to AMD since 2002 is discussed further. This study, therefore, utilises public policy as a lense through which AMD can be approached. The same applies to the socio-economic impacts of AMD (see Chapter 5), which will require policy responses.

The third theoretical element of this study – after sustainable development and the developmental role of water – is the public policy domain. Cloete, Wissink & de Coning (2006: 16–17) considered a number of public policy definitions and concluded that public policy “is a functional perspective on the process of government”; it is not always explicitly articulated but can also be government practices; policy emphasises value judgements, ethics, values, society and relationships; public policy as a process is accentuated; and the importance of management, governance and institutional arrangements in policy must be appreciated. In the most reductionist form, Harold D. Lasswell’s (Farr, Hacker & Kazee 2006: 579) classic notion of public policy as the public process of determining who gets what, when, and how, still remains useful.

Public policy is a well-established disciplinary domain within sustainable development. This study follows in that tradition and thus regards sustainable development as an overarching policy objective. Policy instruments such as water management are then utilised in pursuit of that objective. The pillars of sustainable development are also axiomatically regarded as policy principles applicable to the various policy instruments. In this context AMD in South Africa can be treated as a public policy issue.

2.4.2 The economic significance of mining in South Africa

South Africa has often been described as a world leader in mining. The country has been known for its profusion of mineral resources, and has been responsible for great proportions of world production. South African mining companies are therefore essential role-players in the global industry and so are the reserves (Kearny 2012: n.p.). Historically, South Africa’s economy has been built on gold and diamond mining, as demonstrated by the fact that gold accounts for more than one third of exports, and in 2009 the diamond industry was the fourth largest in the world. It is also a key producer in coal, manganese and chrome (Kearny 2012: n.p). This underscores why it is evident that South Africa’s mining industry has been, and continues to be known as “the bedrock of Africa’s economic powerhouse” (GCIS 2010: 366). This enables the mining industry, along with other related industries, to be essential for South Africa’s socio-economic development. However, with the major contributions that this industry has made to the country, it has still seen a serious decline in its contribution to South Africa's gross domestic product (GDP) over the past 10 to 20 years (GCIS 2010: 366).

Mining contributes significantly to the economy or economic growth in South Africa. South Africa is a country that is wealthy in terms of mineral resources and the growth that it creates for economic development. "South Africa is one of the world's and Africa's most important mining countries in terms of the variety and quantity of minerals produced" and it has the world's largest reserves of chrome, gold, vanadium, manganese and the platinum group minerals (PGMs) (Mbendi 2012). Thus, mining remains crucial and significant to South Africa's economy; for instance, "the Witbank coalfield represents the largest conterminous area of active coal mining in South Africa. These coal fields are known to produce coal for power generation which covers 48% of the country's total power generating capacity for both export and domestic consumption" (Hobbs, Oelofse, & Rascher 2008: 419).

Mike Rossouw (in Creamer 2010) states that mining has a major role to play in nation-building and that management of mining activity should focus on that which is needed to build a sustainable mining industry. He added that "we've got to exploit our natural wealth to the maximum benefit of all the people in this country" (Creamer 2010). There are many who believe that these valuable metals and minerals should be left unexplored and that South Africa should move on to the so-called value-added approach. There are, however, other countries, such as China, that use their resources to their maximum potential and this is what boosts their economic growth which, in turn, is crucial for social transformation. South Africa has 80 per cent of manganese reserves and resources in the world, but only 15 per cent of manganese is produced, compared to China, which produced more than 35 per cent, while having less than five per cent of the world's manganese reserves and resources. According to Rossouw (in Creamer 2010), a country can only be socially transformed through a strong economic base, and the mining industry is what can enable such transformation in South Africa. It is, therefore, evident that the mining industry is extremely important and significant for South Africa.

According to the official *South African Yearbook 2010/11* published annually by the GCIS, mine management forms an essential part of the management of mineral resources in South Africa. In order for this to be managed, the Department of Mineral Resources has to conduct research to improve mine environmental policies, which includes legislation and strategies. It should also provide strategic guidance on mine environmental management, mine rehabilitation, water, ingress, mine environmental legacies and sustainable development. The legacy of mining, which dates back more than a century, has created numerous derelict and ownerless mines that are now leading to severe environmental concerns and health hazards for communities that live in close proximity to these mines. The rehabilitation of these mines needs to be put at the forefront of the department’s priority (GCIS 2010: 368). A draft strategy on Regional Mine Closure in the Witwatersrand and Klerksdorp–Orkney–Stilfontein–Hartebeestfontein gold-mining areas has been developed to address the cumulative mining-related impacts, and to work towards sustainable closure of mines in the areas of concern (GCIS 2010: 368). Susan Shabangu, Minister of Mineral Resources, has established the Rehabilitation Oversight Committee within her department to drive the implementation of a rehabilitation programme for all mines that were licenced before the Minerals Act, 1991 (Act 50 of 1991) (Minerals Act) and the MPRDA came into effect. The costs of this programme and the implementation plan were finalised, and an amount of R52 million has been allocated to the programme (GCIS 2010: 368).

The mining industry, as mentioned above, is a significant industry in the economic growth of South Africa. It covers a “wide-ranging spectrum of minerals in which South Africa has an exceptional geological/mineral endowment” (GCIS 2010: 369). Mineral production has been a key contributor to foreign-exchange earnings and employment in South Africa. In the 1980s the gold sector accounted for almost all mineral-related income. From then, up until 2010, gold has fallen from its prominent position as the main contributor to mineral sales. Employment in the mining industry has seen a decrease of 17.1 per cent from 1997 to 2003. Thereafter, employment figures started to increase since the proliferation of the MPRDA in 2004, peaking at 527 000 in 2008 before the blow of the global financial and economic crisis (GCIS 2010: 369).

From 1986 to 2007 the percentage decline of the mining contribution to the national GDP should be interpreted in the context of the apparent economic diversification and faster growth of other sectors, such as manufacturing, financial services and construction, to which the mining industry also contributed. Regardless of the fact that there have been increases and decreases in the country's economy in the past, the mining sector has been essential and vital to the economic growth. The industry contributed 9.5 per cent to gross value added, 9 per cent to total fixed capital formation and more than 30 per cent to the country's total export revenue, and it employed 2.9 per cent of the country's economically active population, with just over half a million direct jobs and more indirect jobs (GCIS: 2010: 369).

The sector further contributes 18 per cent to the country's corporate tax receipts. The listed mining companies represent over 30 per cent of the market capitalisation of the Johannesburg Stock Exchange (JSE) and, even though the mining industry consumes 15 per cent of national electricity, it contributes more than 95 per cent to the generation of electricity in the form of coal for power stations (GCIS 2010: 369).
South Africa is known for its mineral wealth, which is found in the following well-known geological formations and settings:

- *The Witwatersrand Basin* yields some 93 per cent of South Africa's gold output and contains considerable resources.
- *The Bushveld Complex* is known for the platinum group minerals (PGMs, chromium and vanadium-bearing titanium-iron ore formations, and large deposits of industrial minerals.
- *The Karoo Basin* extends through Mpumalanga, KwaZulu-Natal, the Free State as well as Limpopo provinces.

The world's largest mineral reserves are found in South Africa. This includes PGMs 87.7 per cent in total, manganese 80 per cent, chromium 72.4 per cent, gold 29.7 per cent and alumina-silicates. South Africa also produces over 40 per cent of ferrochromium, PGMs and vanadium mineral commodities globally (GCIS 2010: 372).

Even though South Africa is known for its gold production, it was mentioned already that it entered a decline phase, which will lead towards termination of operations by approximately 2020. There has been a decrease in production by 15 per cent from 252.6 tons in 2007 to 212.7 tons in 2008, dropping from the world's second-largest producer to the fourth largest (GCIS 2010: 373). This was due to mining of lower-grade ore, influenced by higher rand gold prices and the temporary closure of shafts to maintain infrastructure. "About 4.1 per cent of South Africa's gold production was beneficiated to coins and jewellery locally during 2008, generating revenue of R2 billion" (GCIS 2010: 373).

In the Witwatersrand, the geology and gold mines of the Ridge of White Waters are world renowned. Almost half of the gold ever mined came from the extensive Witwatersrand conglomerate reefs that were discovered in 1886 near the Johannesburg city centre. The Witwatersrand is the greatest goldfield known to humankind. More than 50 055 tons of gold has been produced from seven major goldfields distributed in a crescent-like shape along a 350 km-long basin from Welkom in the Free State to Evander in the east (GCIS 2010: 373).

Mining remains a key industry in South Africa; one that creates economic growth and, in turn, enhances the country's economic development. Thus, when a country is rich in resources that bring crucial benefits, it is necessary to ensure that the industry continues to develop. However, despite the enormous significance of the mining industry, it is also responsible for negative impacts and this will be discussed in the next section.

2.4.3 The negative impact of mining in South Africa

"In a water-constrained country such as South Africa, the quality of water determines its suitability for use" (Hobbs et al 2008: 417). Pollution occurs in both surface and groundwater, and is a serious environmental issue that coal and gold mines must deal with (Hobbs et al 2008: 417). "As a consequence AMD from ownerless coal mines in the catchment creates tremendous long-term environmental liabilities for government" (Hobbs et al 2008: 417). However, what is evident is that the private industry, "applying technological innovation to manage AMD plays a vital role in the prevention of environmental and socio-economic degradation through its contribution to sustainable mine water management" (Hobbs et al 2008: 418).

South Africa's gold mining industry commenced in the 1880s and has played an uplifting role in creating some of the country's most important historical milestones, while shaping certain sectors of South African society (Azarch 2011: n.p.). The increasingly difficult issues in the mining industry have caused some mines to shut down as a result of "depletion of the finite resources found within them. With the abruption of mining activities, an ecological process has begun whereby water in these underground mines rises to its previous levels and comes into contact with sulphide minerals, thus becoming highly acidic. The water then reacts with other minerals, which in turn produce other pollutants in the water such as aluminium, lead, zinc, uranium, radium as well as bismuth" (Azarch 2011: n.p.). According to Hamilton (2011: 14) the gold mining industry has made a major contribution to Johannesburg over a period of about 120 years but in the process it "has left us with a looming environmental catastrophe – acid mine drainage".

In the existing literature AMD has increasingly become a topic of discussion and of growing concern. "As a city founded on mining, Johannesburg's legacy is the wealth created, as well as the damage left behind by the careless mining practices of the past" (Guedes 2010: 67). However, these increasing concerns led to the mining industry now being governed by legislation to reduce its impact on the environment.

An important, but contentious, point that appears increasingly in the literature is that the mining industry believes that it cannot be held responsible for the impact of "derelict and ownerless mines". At the same time, the government also remains adamant that it cannot be held responsible for the "clean up" that is needed since it would cost billions of rand to do so (Guedes 2010: 69). The Chamber of Mines works closely with government and the mining companies affected to reach suitable solutions. The chamber is now part of the IMC that has been mandated to address and advise government on this issue. The committee has appointed a panel of experts (including officials from the DWA, scientists from the Council for Geoscience, Mintek, CSIR and the South African Water Research Commission (WRC)) to assist.

Possibilities for plans of action have been drawn up and risks on the AMD issues assessed (Chamber of Mines of South Africa 2010).

Mine owners took advantage of weak governmental regulation by externalising their costs. According to Adler et al. (2007: 34), there is a strong commercial motivation for mining companies to explore possible transfers of water management costs to the government. When a mine can deflect certain short- and long-run production costs to third parties, such as those associated with negative socio-economic and environmental effects, the mine's private costs will be much less and its profits much higher (Adler et al 2007: 34). The "third parties" who must carry the social costs tend to be the surrounding communities and other stakeholders (Adler et al 2007: 34).

The social costs of mining are difficult to predict and regulate. Thus, in the short term these delayed or unpredictable costs make the total social cost appear to be low and phenomena such as AMD to be less controversial. The costs associated with mining include development and operational costs for a specific mine; the cost of prospecting, sinking mine shafts, pumping groundwater, cooling shafts, and developing and employing water treatment facilities; and the costs involved in complying with other environmental regulations (Adler et al. 2007: 35).

When the revenue streams of mines decline and their long-term prospects are negative, their only option is mine closure. Environmental and social remediation or rehabilitation represents costs for mining companies for which they are not prepared or, when liquidated, they cannot afford. In many instance,s the rehabilitation of mining operations becomes a cost for the public sector. These costs include the costs of human and environmental health, and compensation for the social welfare of the former mine workers and surrounding communities (e.g. mining-related health problems). In recent times some mining companies were ordered in court judgments to compensate their former mineworkers for health problems developed in their mines.

The environmental impact of mining takes years to become apparent and for its effects to show. By the time that the environmental and socio-economic consequences become noticeable, the mine has already closed or has become insolvent and therefore can no longer be compelled to contribute to remediation, either financially or through other actions (Adler et al. 2007: 35). The historical relationship between government and the mining sector, and the emphasis on mining's contribution to economic development in South Africa have led to a public perception that government is unable or unwilling to properly regulate and manage mine water and mine waste (Adler et al 2007: 36).

Since 1997 South Africa has produced almost 468 million tons of mineral waste per annum (Oelofse et al. 2007: 1). Gold mining was estimated to account for 221 million tons, or 47 per cent, of all mineral waste produced in South Africa. Thus, making mining the largest single source of pollution and waste. It is now widely assumed that AMD is responsible for the most costly environmental and socio-economic impacts. The pollution caused by gold mining waste is illustrated by the developments in the West Rand area where decanting from gold mines started in 2002. The West Rand case demonstrates some of the technical, socio-economic and governance challenges faced by the industry and regulators in managing the negative impacts that arise from mine waste (Oelofse et al 2007: 1).

In addition to scholarly publications, government departments and NGOs involved with AMD also publish official documents or comments and reports in the media and on the social networks. The impact of mining on a wide range of sectors often receives their attention; for example, according to the Department of Mineral Resources, the mining industry has to abide by sustainable development principles (DMR 2012: 5). Mineral resources are non-renewable in nature, thus, exploiting such resources must balance connected economic benefits with social and environmental needs, without restricting their use for future generations. Every mining company must implement elements of sustainable development commitments and this includes implementing environmental management systems, also ensuring that mining activities do not have an effect on the health of communities and should be taken into consideration (DMR 2012: 5).

The increase in mining throughout the country may be beneficial for certain sectors of the South African economy, as more mines lead to economic growth. However, other sectors often tend to suffer from mining such as agriculture, tourism and biodiversity, because important natural resources are lost in the process (CER 2013). The Federation for a Sustainable Environment (FSE), an NGO that is involved in environmental activism tends to be concerned about the unsustainable use of the country's natural resources.

In conclusion, according to the IMC (Coetzee et al. 2010: 37), mine flooding (and, by implication, also AMD) is not something new; this problem has been around for centuries. The reason why it is a concern now is due to the extent of the problem and the fact that more mines are now left ownerless and abandoned than in the past. Once the mines are abandoned, pumping of the underground mine water stops and with the rising water levels, acidic water starts to form.

2.5 Conclusion

The purpose of this chapter was two-fold: (1) to present a review of the literature that already exists on AMD in South Africa, and other aspects of mining and sustainable development, and (2) to develop a theoretical framework on the basis of this literature that can be applied in this study.

The first conclusion is that extensive literature exists on mining in South Africa and also on the technical-scientific aspects of AMD (such as the IMC expert report) but very little exists on its socio-economic impacts. The discussion about the current state of AMD in Chapter 3 will underscore this conclusion. This lack of research and publications serves as additional justification for conducting this study.

The second conclusion is that the literature on sustainable development and its relationship with water sufficiently incorporates the elements of human development, socio-economic development, community-focused analysis and environmental impact relevant for AMD to serve as a basis for a theoretical framework. The disciplinary focus of public policy within sustainable development will constitute the third element of the framework. It implies that the theoretical approach of this study is grounded in, or integrated into, the literature it used as the foundation for the research.

CHAPTER 3: THE NATURE OF ACID MINE DRAINAGE IN THE VAAL RIVER SYSTEM

3.1 Introduction

The purpose of this study is to consider the possible socio-economic implications of AMD in the Vaal River system. It is therefore necessary first to develop an overall understanding of the state of AMD in this area. Research has been done in this respect until late 2013 to determine the latest state or nature of the phenomenon.

Such an approach gives the researcher and reader an indication of the magnitude, severity and urgency of the problem. It sheds light on whether AMD poses an impending crisis or whether it is a manageable problem. On what scale is the potential or real threat for human beings and the environment? What is AMD's potential impact on socio-economic sustainability in the region?

It is not the intention of this research to reach an independent conclusion about the scientific state of AMD, because it is not a geoscientific or engineering study. It depends on the different scientific studies already available in this field, as well as the opinions of AMD experts, reporting in the media and affected stakeholders. The objective is rather to determine if there is a consensus about AMD as a phenomenon in the Vaal River system. If it does not exist, why not and what are the different opinions? Such an evaluation is also relevant for Chapter 4, which deals with the responses of government, NGOs and the private sector to AMD. Their understanding of the current state of AMD determines their proposed response.

In Chapter 2 the existing literature on the topic was discussed. In this Chapter (Chapter 3) the research conducted was to determine the nature of AMD in South Africa and what its potential developmental significance could be is presented. The latter aspect, with a few rare exceptions, is almost nowhere to be found in the existing literature. The chapter concentrates on the Vaal River system and the three basins in the Witwatersrand. The various role-players in the AMD debate present different, and sometimes conflicting, views. These opinions are explained here.

Different sources were used to determine the current state of affairs in the three basins in the Vaal. They include the expert report submitted to the IMC; consultant reports; interviews with government officials, NGO staff and consultants; and media reports that also relied on government officials, NGOs and experts' comments and information.

3.2 Acid Mine Drainage

AMD affects many provinces in South Africa, which include in particular Gauteng, Mpumalanga, North West and the Free State. Its potential threat to the Johannesburg central business district (CBD), and other economic and population centres has also become clearer in the last few years (Guedes 2010: 69).

A major environmental problem relating to mining in many parts of the world is uncontrolled discharge of contaminated water from abandoned mines. This is one of the manifestations of AMD. "Acid mine drainage [originating from underground mine water] is produced when sulphide-bearing material is exposed to oxygen and water. The production of AMD usually, but not exclusively – occurs in iron sulphide-aggregated rocks. Although this process occurs naturally, mining promotes AMD formation simply by increasing the quantity of sulphides exposed" (Oelofse et al. 2007: 2). AMD is characterised by low pH (high acidity) and high salinity levels in the water emerging from underground as well as surface water polluted by mine waste (DEAT 2008: 1). AMD is said to originate from both surface and groundwater workings; waste and development rock and tailings; and piles and ponds. AMD is not only associated with surface and groundwater pollution but is also responsible for the degradation of soil quality and aquatic habitats, and for allowing heavy metals to seep into the environment. The South African government's view is that "an exacerbating characteristic of AMD is its persistence – it is extremely difficult to rectify" (DEAT 2008: 1).

It is important to note that the general public's view of AMD – which only includes underground acidic mine water that contaminates surface water – does not encapsulate all its manifestations. What happens not only underground but also above the mine shafts with the mine waste is very important to take into account.

Therefore, “AMD probably presents the single most important factor dealing with tailings and waste rock and their impact on the environment” (Oelofse et al. 2007:2). Moreover, it is important to consider the possible impact that AMD can have on long-term pollution, as AMD could continue for years after mines have closed and tailing dams (or popularly known as mine dumps) decommissioned. It is widely assumed that AMD is responsible for costly environmental and socio-economic consequences. Therefore, significant improvements are made in developing policy frameworks that can address mine closure and mine water management. The mining industry is also changing its practices and routines to conform to new legislation and regulations, but there are still persistent vulnerabilities in the current system.

It is assumed that AMD is increasing in its severity to the extent that the mining waste can result in profound, often irreversible, destruction of ecosystems. This view is one of the contested points in the debates in the South African context. Environmental activists and NGOs generally maintain a pessimistic view. They even say that in certain instances it might be impossible to rehabilitate the polluted sites at all, because pollution is so severe that there is no method to remedy this destruction. The scientists and researchers in the field, however, are more pragmatic and use examples to demonstrate measurable improvements in the quality of aquatic life or changes in the pH levels of water systems, especially those in the Western basin near Krugersdorp. This point is a good illustration of an ongoing tendency in the AMD debate in South Africa that will be discussed in other parts of this study as well, where there are differences in opinion, often among scientists but also between the scientists and public activists. Shanna Nienaber is notable for her research on this matter.

In South Africa the occurrence of AMD tends to be increasingly common in several parts of the Witwatersrand and the Highveld coal fields in Mpumalanga Province close to Middelburg and eMalahleni (formerly Witbank). Acid mine water began to decant in significant quantities from defunct flooded underground mine workings on the West Rand in the Gauteng Province in August 2002. In 2008, one of the government departments affected by it, made the following observation about the Western basin:

> In South Africa, an example of AMD is occurring on the West Rand in Gauteng Province. Acid mine water started to decant from defunct (closed) or flooded underground mine workings on the West Rand in August 2002. Decant has subsequently been manifested at various mine shafts and diffuse surface seeps in the area. Up until early 2005, and completion of storage and pumping facilities to contain and manage on average of 15 ML/d of decant, the AMD found its way into an adjoining natural water course and flowed northward through a game reserve, and towards the Cradle of Humankind World Heritage Site. (DEAT 2008: 2.)

AMD is not only linked to surface and groundwater pollution, but is also responsible for the degradation of soil quality, for harming aquatic sediment and fauna, and for allowing heavy metals to seep into the environment. However, many stakeholders involved in the matter maintain the view that it can be managed. According to Oelofse et al. (2007: 3), AMD can be controlled best by controlling water entry into the site of acid formation by diverting the surface water away from residue storage areas, by preventing groundwater infiltration into the mine workings, by preventing hydrological seepage into the affected areas and by controlled placement of acid-generating waste.

In a similar vein, according to Kearny (2012: 12), “Acid Mine Drainage does not have to be a problem. The water can be treated to produce drinkable quality, and the polluting elements can be turned into useful products. However, finding a way to finance a solution that balances the rights and obligations of all the parties involved have proven to be difficult.” The South African government’s IMC supports a similar sentiment and its research document states that the issue of AMD will need to be controlled, managed and treated. Steps that need to be taken have been researched and studied globally and in South Africa.

According to the IMC (in Coetzee et al. 2010: 3),

> AMD is a significant and costly environmental impact of the mining industry worldwide. The legacy of mining continues to affect surface and groundwater resources long after mining operations have ceased. AMD is a common

problem at abandoned mine sites around the world today. The oxidation of sulphur-rich mine wastes by interactions with water and oxygen and the consequent release of AMD is one of the main environmental challenges facing the mining industry.

3.3 How Acid Mine Drainage is Defined Among the Various Actors

The definition of AMD is very important, because it largely determines how the phenomenon is assessed. The narrower it is defined the easier it is to be addressed. A narrow definition that concentrates on a specific aspect that can be restricted or confined will therefore be easier to address. A definition broader in its scope that includes more complex phenomena is obviously more difficult to address. Therefore, if a spokesperson claims that AMD is under control, it often depends on the definition used in that case. Two broad categories of definitions are used: one that concentrates exclusively on underground mine water which turns acidic and then decants at the surface to contaminate surface water systems, and another category, which in addition to the underground water, also includes radioactive acid water formed by the interaction between acid rain and tailing dams, and which results in a limited radioactive responsive. These categories are broadly associated with the South African Government's definition, in the first instance, and civil society activists, researchers and consultants, in the second. The first category of definitions of AMD, in particular, is found in both the literature review discussed earlier and in the personal interviews with government officials conducted for this study. After comparing the different definitions of AMD, one can form a better understanding of how this issue has become the emergency it is today.

First the definitions that look at AMD from a broad perspective and that are mainly associated with researchers and consultants such as Anthony Turton or activists such as Mariette Liefferink are discussed. According to Turton, a number of different acid-forming processes are known but all of them involve similar chemical elements, and they include acid rock drainage and AMD. Another distinction can be made between surface manifestations and sub-surface manifestations that are all caused by the oxidation of pyrite which produces acid in the presence of oxygen and bacteria. The necessary condition for this to occur is a minimum acid level of pH5.

Thus, in summary, according to Turton (personal interview, 2013), ‘AMD’ is defined as “water that is acidic arising from the oxidization of pyrite, below pH5”, thereby referring to this aspect of AMD on which most stakeholders have reached consensus.

The next element of AMD is controversial and especially government representations do not refer to it at all. It affects mine residue areas (MRAs) on the surface where the fine sludge or residue of the crushed mine rocks are stored in tailing dams. Below the pH5 acid level, according to Turton, when acid rain comes into contact with the mine dust on the tailing dams there is a “mobilisation of uranium” which does not happen above pH5. The radioactivity of uranium combines with the high acidic and salt levels of the mine water to form a more complex form of contaminated mine water. Thus, pH5 is the defining threshold, especially in the Witwatersrand goldfields for both forms of AMD. This conclusion about the catalyst effect of acid rain, according to Turton, was the result of the latest research on the chemistry of AMD and the formation of acid. At present rainfall with a pH of as low as 3 has been observed in the Vaal River system and acidic rain falling on top of mine dumps triggers the initial formation of acid, which drops the pH and then triggers the second phase. Turton is one of the first persons to accentuate the importance of acid rain in combination with AMD, with the implication that even if the underground formation of acid water can be reduced or arrested, it will not be the end of AMD. However, acid rain is a phenomenon that has not yet been brought to the attention of the South African public and has not yet been looked at by the media when discussing AMD (Turton, personal interview, 2013). During an interview with AgriSA, interviewees were asked about their understanding of acid rain. They responded that there was an impact but that it was limited and they were not aware of this with regard to AMD (AgriSA, personal interview, 2013).

AMD occurs in many parts of the world but, in the opinion of Turton, it is locally specific, because of the South African geology and hydrology. It is a nuanced situation and nuanced by localised conditions: the water situation in general and mine water in particular are not the same everywhere. The case of “the silver bullet, one size fits all” definition of AMD does not apply in South Africa and, more specifically, not in the Vaal River system (Turton, personal interview, 2013).

Mariette Liefferink is an environmental activist of the FSE who provides services to communities and addresses the injustices regarding the environment such as AMD. Liefferink's main focus is on radioactivity which overlaps with Turton's linkage of acid rain to AMD. She states that the gold mining industry in South Africa is in decline and therefore an increasing number of mines are decommissioned. As a consequence, the risks of AMD are increasing, because mining companies are no longer taking responsibility for managing the underground water and the tailing dams. In her view, decanting of AMD after the closure of mines is an enormous threat and could become more severe if remedial activities are not implemented as soon as possible (Liefferink, personal interview, 2013). Waste from gold mines, according to her, constitutes the single biggest source of waste and pollution in South Africa and AMD is responsible for the most costly environmental and socio-economic impacts. AMD can continue for years to come after mines have been closed and tailings dams decommissioned. AMD, according to her, can lead to long-term exposure of polluted drinking water and can pose a threat to human health in the form of increased rates of cancer, decreased cognitive functions and the appearance of skin lesions (Liefferink 2012). Heavy metals in drinking water can also compromise the neural development of the fetus which can lead to mental retardation (Liefferink 2012). Liefferink's implied definition, underlying her description of the implications of AMD, is very similar to Turton's, except that she concentrates more on the radioactive dimension, while he considers it less prominent and, therefore, also posing less of a threat to the environment.

The next category includes definitions from a narrower perspective and is presented by two persons who work in the sphere of government or are closely related to it. Their definition of AMD is markedly different from Turton's and Liefferink's, and this can explain why the official government view of the current state of AMD is less alarming than those of Turton and Liefferink. Bashan Govender from the national DWA (Govender, personal interview, 2013) defines AMD in terms of how it is formed. He embraces the conventional approach about how mine water becomes acidic. According to him, in gold mines the iron sulphide reacts when it comes into contact with oxygen and water, and produces extremely acidic water. This water then dissolves other metals and salts in the mines, and when the water decants on the surface, it constitutes AMD. Due to the dissolving of salts (which results in high saline levels) and the high acid levels, this leads to a low pH level which will not sustain any aquatic life in the water and when it reaches the natural environment, it will disrupt plant life. Govender adds that since the late 1990s, many mines have closed down in Gauteng because of the economic downturn and a decline in gold as a commodity. These closures meant that the water in the mines was left to rise to the surface without any management of its possible consequences (Govender, personal interview, 2013). It is clear that this definition and discussion of AMD does not include any reference to the problems caused by tailing dams and acid rain, and their contribution to AMD. It is confined to underground mine water and how the decanting should be managed.

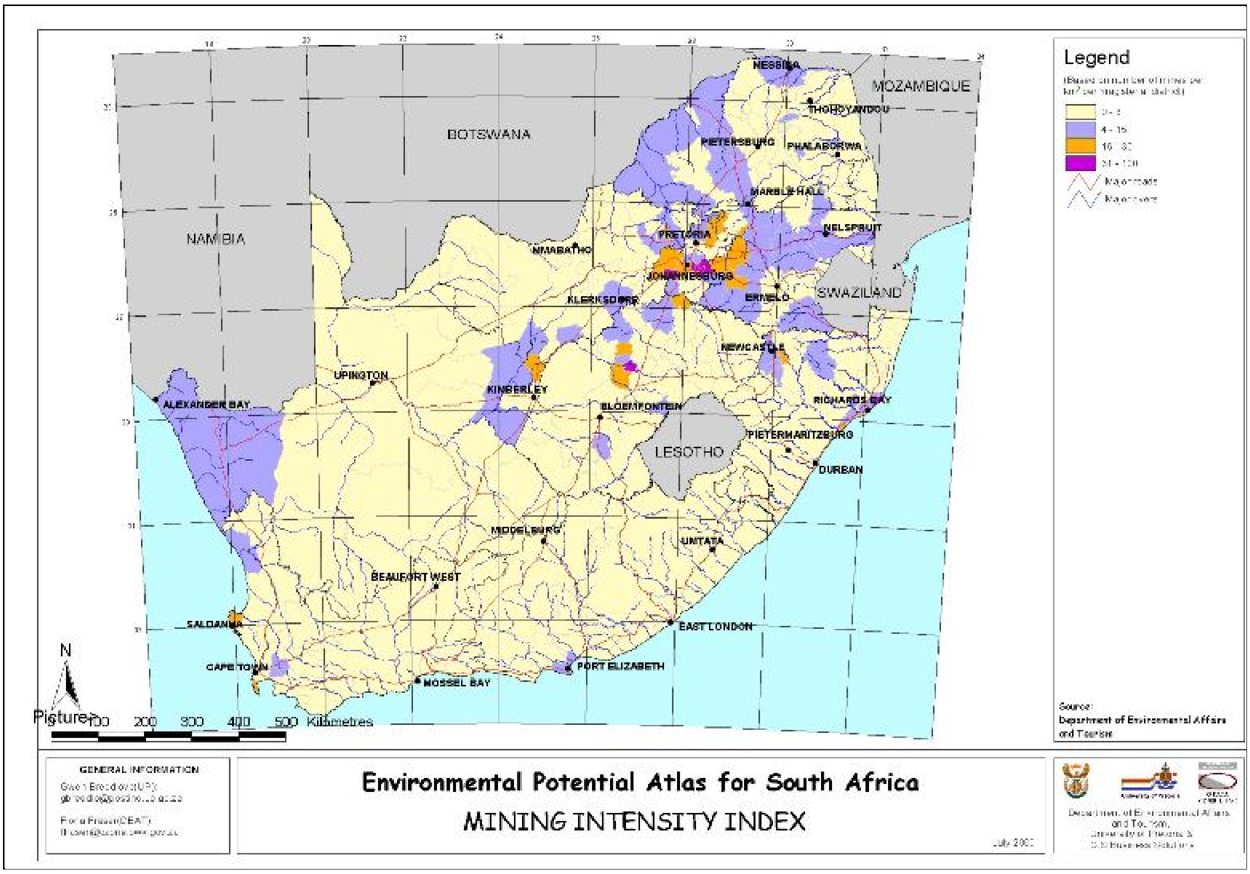
Peter Kelly from the DMR (personal interview, 2013) follows the same approach as Govender, because he also concentrates on underground mine water and how it can affect surface water systems. He explains how evident it is that the water decanting from the mines is acidic and generally polluted, because when it comes into contact with the surface water one can see the iron particles which have a bright red colour (Kelly, personal interview, 2013). He also does not refer to the systemic problems caused on the surface by tailing dams and the complication of acid rain for AMD.

In conclusion, the discussion has demonstrated that AMD in the Vaal River system is defined in at least two different ways, while within these two groups of definitions internal nuances are also present. These differences and nuances are important to understand in order to grasp the main issues in the AMD debate and also to determine its possible socio-economic consequences.

3.4 The Vaal River System

This focus of this study is confined to the Vaal River system and, therefore, it is necessary to provide a brief description.

The Vaal River system is the main geographical focus of this study and it is affected by one of the most concentrated mining areas in South Africa. The map (Figure 3.1) illustrates the mining activity in South Africa.

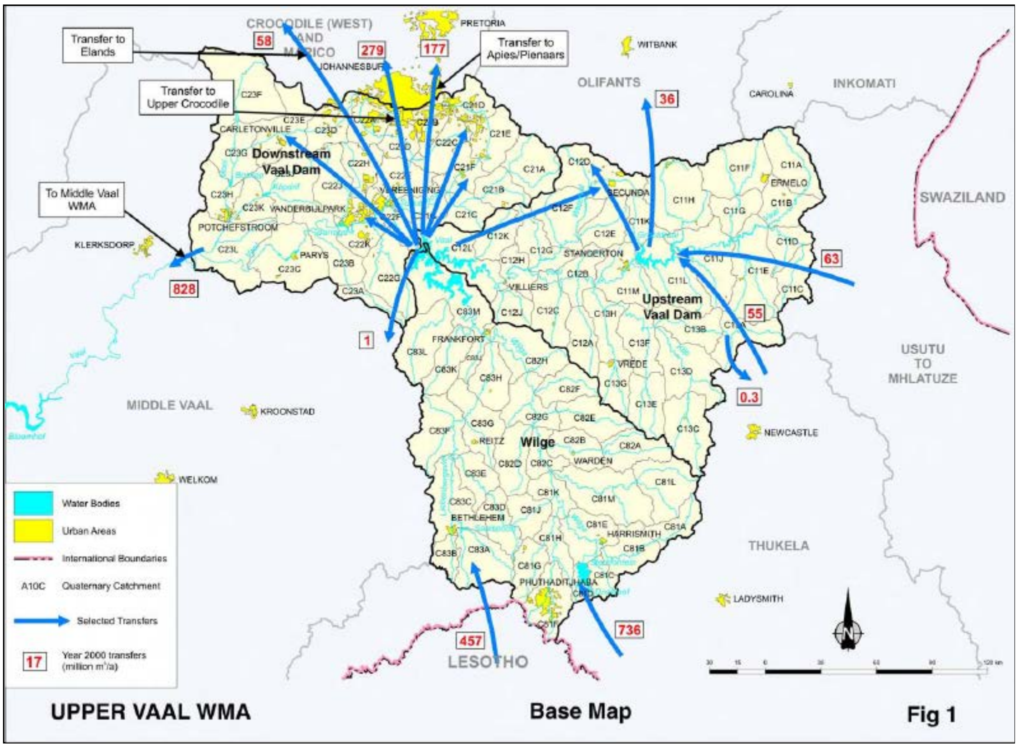


(Source: Van Viegen, van Riet & Claassen 1997)

Figure 3.1: Environmental potential address for South Africa: Mining intensity map

The Vaal River is 1 120 km in length and it supports about 12 million consumers of water in Gauteng and other areas (DWAF 2009: n.p.). The main tributaries of the Vaal River are the Harts, Vals, Waterval, Bamboesspruit, Blesbokspruit, Mooi, Vet, Renoster, Riet, Wilge, Klip and Liebenbergsvlei rivers. There are three water management areas (WMAs) in the Vaal River system: the Upper, Middle and Lower Vaal WMAs. The one most relevant to AMD is the Upper Vaal WMA 8. The Vaal River system is one of the most important elements of the 19 WMAs in South Africa and the other main river systems are the Orange, Limpopo, Olifants and Tugela river systems (DWAF 2009: n.p.).

The Vaal River system originates on the eastern Highveld plains in the Ermelo area. "Shallow hollows and low hillocks form a natural sponge where water collects in pans, vleis and streams. These streams link up and the Vaal River is born, flowing westward on a long course, without rapids or waterfalls, broadening into a large river" (Rand Water 2012). The Vaal Dam is known as the most important dam in the system due to it being the primary supplier of water to the "economic heartland of South Africa" in Gauteng. It is managed by the Rand Water Board (Rand Water 2012). Some of this water originates from Lesotho and through the Lesotho Highlands Water Project (managed by the TCTA) it is pumped to Clarens in the eastern part of the Free State Province and from there fed into the Vaal River system. Figure 3.2 illustrates the Upper Vaal MWA 8 and the main area of focus of this study.



(Source: Basson & Rossouw 2003)
Figure 3.2: Upper Vaal Water Management Area 8

The Vaal River system is the most crucial source of water in South Africa. It is "not only crucial to human life, but to agriculture, industry, aquaculture and an entire aquatic ecosystem" (Cele 2009). The economic activities especially in the Gauteng Province and the traditional mining areas are, however, also the cause of serious deterioration of the water quality of the river (Cele 2009). It poses the classic dilemma of developing countries which require a delicate balance between economic growth and development, on the one hand, and sustainable human development which is sensitive about the natural environment, on the other.

In 2010 the DWA undertook a series of Reconciliation Strategy Studies for all large water river systems supplying the metropolitan areas in South Africa with water. These studies set out to identify future water requirements for each area in close collaboration with the users which included methods to reduce the demand, to study possible further resource development options and to develop strategies to ensure continuing supply of water for the next 25–30 years. Several stakeholders were involved in the committee which included the DWA, provincial and local governments. The committee was set up to monitor the implementation of the strategies, update the strategies with new information when needed, make recommendations to the institutions responsible for the strategy, and to communicate progress to the stakeholders and the public (Van Wyk, Rademeyer & van Rooyen, 2010: 1–2).

According to van Wyk et al. (2010: 2),

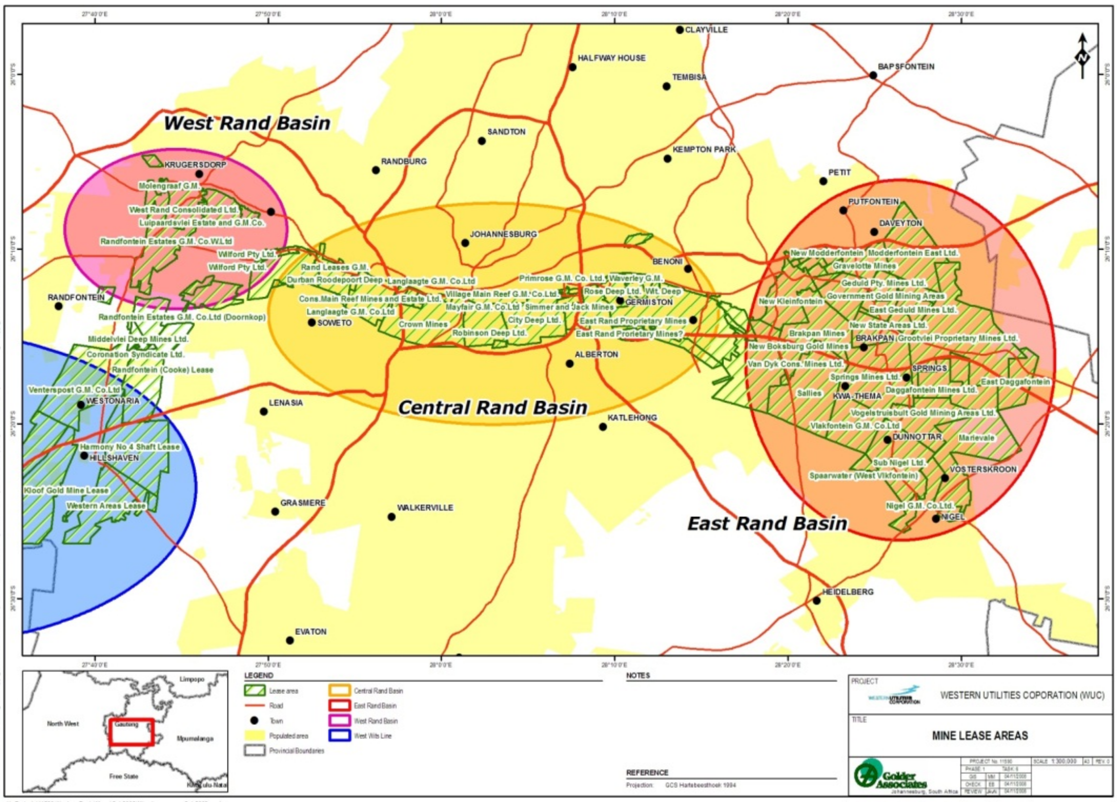
> The area supplied by the Vaal River System stretches far beyond the catchment boundaries of the Vaal River and included most of Gauteng, Eskom’s power stations and Sasol’s petro-chemical plants on the Mpumalanga Highveld, the North-West and Free State goldfields, Kimberley, several small towns along the main course of the river, as well as irrigation all along the main stem of the river and the large Vaalharts Irrigation Scheme.

A considerable amount of water is channelled from the Thukela, the Usutu and the Senqu–Lesotho rivers to the Vaal River. It is used as a channel to transfer water to the Upper, Middle and Lower Vaal WMAs. “Significant water transfers out of the Upper Vaal WMA occur through the distribution system of Rand Water to urban and industrial users in the Crocodile West and Marico WMA” (Van Wyk et al. 2010: 2). Water has also been transferred to the Olifants WMA in order to supply the power stations in that region.

The Vaal River System Reconciliation Strategy identified several actions to ensure that sufficient water would be available to users. One of these included undertaking a feasibility study to reuse water, with underground mine water from gold mines being a priority (Van Wyk et al. 2010: 3). These actions were approved by the top management of the DWA and the then Minister. AMD is one of the "key contributors to salinisation of the integrated Vaal River System" (Van Wyk et al. 2010: 3).

3.5 The Status of Acid Mine Drainage in the Three Vaal River Basins

In the introduction to this study it was indicated that the purpose of this chapter is partly to determine the current nature and state of AMD in the Vaal River system. It was also indicated that the system is divided into three basins. This section therefore takes a closer look at the current situation in the basins, the potential threat of drainage and what the expectations are for the near future. Figure 3.3 illustrates the areas surrounding each of the three basins.



(Source: Liefferink, M. 2012. Federation for a Sustainable Environment)
Figure 3.3: The three basins in the Witwatersrand

Firstly, a number of general observations have to be made. The attention generally given to AMD is divided between two regions: (1) the gold- and uranium-producing mines on the Witwatersrand, where AMD commenced in 2002 mainly in the Western basin, and (2) the coal-producing mines on the Highveld in Mpumalanga Province.

The experience of Carolina became a well-established precedent of the complications there.

The management of mines, and especially of their closure, is a critical factor for appreciating the complications of AMD. As discussed in section 2.4.2 on the economic significance of mining, the mining industry has created much development for South Africa and has contributed highly to the country's economic growth. However, in section 2.4.3 some of the negative impacts of mining were highlighted, such as abandoned mines, which is linked to the focus of this study namely AMD. "South African mining companies are not fulfilling their obligations to set aside money for mining clean-up operations before they are officially closed" (Wait 2012a). This particular media response in the *Mining Weekly* highlights the continuous concerns of environmental degradation in the mining areas, stating that the large number of ownerless and abandoned mines, and AMD incidences have shown there is a need for improved environmental maintenance and rehabilitation in the mining sector (Wait 2012a). Profits made from mining were not used to pay for the environmental damage.

"While jobs and revenue generated by mining are essential to the South African economy, the costs of mining borne by the environment, mine neighbours, downstream water users and the taxpayer are an unacceptable consequence of a poorly managed sector" (Wait 2012a). Thus, while the economic significance of mining is highlighted here, at the same time, one is confronted with the extreme dilemma of the cost to the environment (Wait 2012a). These problems largely concern the quality of environmental management programmes or the fact that the plans are not adequate and do not consider longer-term water quality issues.

Though not directly the subject of this study, the situation in Mpumalanga, and specifically in Carolina, is informative of the possible impact of AMD and it has received substantial public attention, including its socio-economic (especially health) impacts. Carolina residents are already suffering from the consequences of AMD and during 2012 have not had access to tap water for months, due to the water being contaminated with chemicals such as sulphate, aluminium, chromium, manganese, cobalt, lead, zinc, copper and nickel. It is assumed that if affected water is consumed, it will lead to chronic health problems for residents, especially diarrhoea (Yende 2012: n.p.).

The media is playing an important role in creating more public awareness about AMD. An important element of the potential impact of AMD is the public perception about its state of affairs and in that respect the media is the most important role-player to influence or determine that perception. Masondo, du Plessis, Mclea and SAPA (2011: n.p.), for example, described AMD as "a ticking time bomb beneath the country's richest province." The severe weather that occurred in January 2011, which caused human deaths, also raised the levels of toxic water in Gauteng's mines. Public involvement is encouraged to create more awareness and to put pressure on the stakeholders to implement a response plan.

A significant comment in *The Star* (Wende 2011: 14) was that "it is time for those of us who are not experts on this matter to begin asking questions and demand that role-players take action". Experts stress that serious decanting that will start to affect parts of Central Johannesburg is imminent. This media comment states that citizens need to take a more active stance and understand what is happening, and that government should take responsibility for the long-term damage to the environment. "AMD is an issue that will affect millions of people all around Gauteng" (Wende 2011: 14). This 2011 media article stressed the issue of decanting taking place in the West Rand and starting to increase in the Central basin. Other media reports have already begun warning about the possible impact on Central Johannesburg (Wende 2011: 14).

One of the most comprehensive studies so far on AMD was done by an expert group for the government's IMC in 2010. According to the IMC, there is an overall understanding of the AMD issues in South Africa. The IMC document did not regard the situation as critical and concluded that there was still sufficient time to address these issues and that decisions relating to mine water, its potential impacts, management strategies and treatment technologies in the Witwatersrand Gold Fields would be made. The areas that were under investigation for AMD interventions were the Witwatersrand Gold Fields, Mpumalanga (Carolina), KwaZulu-Natal Coal Fields and the O'Kiep Copper District. The Vaal's Western, Eastern and Central basins were regarded as priority areas. Though not alarmist about the situation at the time, the report concluded that these areas were in need of immediate action. The Western and Central basins were said to be most affected in 2010.

Peter Mills (personal interview, 2013) from the Cradle of Humankind, in a more recent general assessment of the AMD threat, stated that the water quality was not in a good condition in the Western basin and that the Central and Eastern basins would not decant, because government would not let it happen. He said that if nothing was done, then the Central basin would start decanting by 2014 and the Eastern basin by 2015. The most important measuring instrument for determining the potential AMD threat is the environmental critical level (ECL), which is the highest level that mine water is allowed to rise before extreme impacts of water in the mine shafts are experienced. If pumping of underground water is the preferred approach towards containing the threat of AMD, mine water must be kept below the ECL. According to Mills, the government keeps a close watch on the ECL and will, therefore, not allow central Johannesburg or the Gold Reef City theme park to flood.

From the interviews with AMD experts it emerged that rainfall patterns are an important consideration that has to be included in an assessment of AMD. Mills stated that the rainy season of 2010/11 had spiked this problem and Govender (personal interview, 2013) agreed, stating that mine dumps could only absorb a certain quantity of water and once it did, the rest had to come out at some point. Govender stated that during 2002/10 the rainfall pattern was not as bad as in the 2010/2011 period. This he described as an abnormal rainy season, and one of the wettest (Govender, personal interview, 2013). The Western basin filled up and could no longer handle the volume of water, which was partly the issue. He also stated that there could be aggressive seasons ahead that required planning (Govender, personal interview, 2013).

A more detailed discussion of the three basins is provided below.

3.5.1 The Western basin

The Western basin around Krugersdorp was the first area where major decanting of acidic mine water had taken place since 2002. It might therefore also be regarded as the area most affected by AMD so far. Two areas in the basin have received substantial public attention, (1) the Cradle of Humankind as part of the Sterkfontein caves, which is a World Heritage site, and (2) the Krugersdorp area, and specifically the environmental impact of AMD on the Nature Reserve and the Tweelopiespruit.

General agreement exists that AMD has become a public issue since its emergence in 2002 (personal interviews: Liefferink 2013, Kelly 2013, Mills 2013, Govender 2013, Turton 2013). Since 2005 increasingly more attention has also been paid to the Cradle of Humankind in particular. This phenomenon has been researched for more than eight years already and is the focus of public attention.

When the last gold mine in the Krugersdorp area stopped underground operations in 1998, dewatering pumps were switched off and the natural regional groundwater levels started to rise to levels last seen many decades ago. There is strong evidence that input such as sewage waste also contributed towards deteriorating regional water quality, although little attention has been paid to this (Cobbing 2008: 454).

According to Ho (2011: n.p.), since 2002 there has been toxic water in the Krugersdorp Nature Reserve. The acidic water is affecting the wildlife in the water. However, also of concern is the fact that it may cause blindness and damage to the retina of both humans and animals.

The scale of contamination is enormous. “Seepage and percolations from sludge dams amount to 24 tonnes of uranium water entering that region’s water basins and river systems annually, this includes the Vaal River” (Ho 2011: n.p). This remains a problem that extends across the gold mining areas in Gauteng, and in the West Rand it is a threat to the fossil wealth of the Cradle of Humankind. The residents in the Krugersdorp area who are reliant on borehole water are affected by mine water decanting. They have raised concerns about the “orange colour of the water” which is the result of sulphur compounds present in acidic water. The South African

Council for Geosciences (CGS) also warned that the acidic mine water in some areas contained high levels of radioactivity which may increase the risks of cancer (Oelofse et al. 2007: 6).

Some observers describe the Western basin as “a write-off” (Liefferink, personal interview, 2013). During a tour to the Western basin and the Krugersdorp area with environmental activist and CEO of the FSE, Mariette Liefferink, the extent of the AMD crisis became real. Liefferink explained how mine water in the observed areas had severely decanted, and she also explained the nature and severity of the decanting phenomenon and provided her views on why this was the situation in the Western basin. Figures 3.4 to 3.7 illustrate the sites visited in the West Rand.

(Source for photograph: Researcher)
Figure 3.4: West Wits Pit (Western basin, Krugersdorp)

(Source for photograph: Researcher)
Figure 3.5: Robinson Lake (Western basin, Krugersdorp)

(Source for photograph: Researcher)
Figure 3.6: Robinson Lake (Western basin, Krugersdorp)

(Source for photograph: Researcher)
Figure 3.7: Mariette Liefferink explaining the radioactivity caused by AMD

Liefferink predicted that while the Western basin had already started decanting and experienced flooding, the other basins would soon follow. According to her estimation, only about 21 per cent of the Vaal Barrage was not yet toxic. What is alarming in her argument is her concern for the Western basin, stating that it was already fully flooded which had enormous ramifications for the area. In addition to the water quality, she also warned that acid rock dumps in the area contained about 6 000 tonnes of heavy metals that could potentially also dissolve into the water. The overall response to AMD she regarded as “a band aid approach” in the sense that AMD would continue and would remain unaddressed.

Bashan Govender from the national DWA commented on the Western basin in February 2013, stating that the flow was in a northerly direction towards the Tweelopiespruit. People have complained about not being able to use the water. There have not been complaints from areas that are serviced by Rand Water. However, he stated that water was rising on a daily basis (Govender, personal interview, 2013).

According to Peter Mills (personal interview, 2013), some geologists believed that the Cradle of Humankind could be under threat, but others did not. As an official of the Management Authority of the Cradle of Humankind, he explained the water dynamics of that area. According to him, as its name indicated, the Witwatersrand extended along a ridge (“rand”) and all the mines were on top of it. From Randfontein, some of the river systems flowed north and others south to the Orange and Vaal River systems. The Blesbokspruit runs from Krugersdorp and collects the sewage water that is decanting into the system. In the nearby Tweelopiespruit the mine water decants and flows straight into the river system, down into the Rietvlei Dam and into the Cradle of Humankind. It then joins the dolomite formations in the area of the Sterkfontein caves and the water separates into two directions. Some of the water flows into the dolomitic compartments, and some remains on the surface and flows into the Crocodile River that enters into the Hartbeespoort Dam. Thus, the river loses water that enters the dolomite formations where its acidic level is partly neutralised by the alkaline nature of the dolomitic elements. Some of this underground water joins the river again where the water table is close to the surface and by the time it reaches the Crocodile River the water is no longer the same as it is near Krugersdorp. Therefore, Mills concluded that contamination was from surface water. He stated that the mining companies were responsible for that and should take responsibility. At the same time Mills warned that if the public reacted in too much haste and demanded too much of a response too quickly it could be counter-productive. It could place too much unnecessary stress on this issue, which could delay any results. Mills conceded that AMD had had some visible effects on the Cradle but these effects were more visible in the river above the Cradle River than in the Crocodile River itself (personal interview, 2013). Thus, the impact was more on the surface, closer to the point of decanting, but it remained difficult to state what percentage of the Cradle was affected by the acidic mine water.

The media in general presented a more serious assessment of the situation in the Cradle. In April 2005 the media started drawing attention to the West Rand basin with specific warnings that the Cradle of Humankind was being affected by AMD (DEAT 2008: 2). There were reports that “South Africa’s renowned Cradle of Humankind in Gauteng, home to one of the world’s richest hominid fossil sites, is under threat from highly acidic water pollution and it is also threatening to drown the

Sterkfontein caves”. This is in line with the conclusion in the IMC’s document in 2010 that the Western basin was of critical concern to the government (Coetzee et al. 2010).

Another perspective (Hamilton 2011: 14) was that the West Rand and the area around the Cradle of Humankind, which was once “our pristine waterways of the Witwatersrand”, were by 2011 extremely acidic and hopelessly polluted, with the damage increasing daily. At that time, according to Hamilton (2011: 14), the Sterkfontein caves were clear of AMD but monthly water quality monitoring was undertaken and joint reporting by the CSIR and the CGS experts were to ensure that the site was not compromised due to unregulated closure of mines or mines that were simply abandoned at the end of their production cycle. The area around the Cradle calls for a sustainable approach to mine and water management so that for the future clean water can be secured for the protection of the fossils in the Cradle of Humankind and also for the communities that rely on the water from the rivers.

Bashan Govender (personal interview, 2013) made the point that the three basins were not interlinked by aquifers or tunnels and, therefore, whatever was pumped into the Western basin had no effect on the other basins. The basins were all separated by geological formations. “It is a contained system – what you pump in the one basin, has no effect on the other basin” (Govender, personal interview, 2013). In the Western basin, Govender stated, decanting had stopped and water that was substantially reduced in heavy metals was now delivered in the river system. A salt content of about 40–50 per cent and its low pH level were not suitable for the environment. Govender explained, that was not the ideal solution and the challenging factor was that the treated water was still very high in sulphates which, in itself, was not toxic but the water was not considered ideal for human use because it could cause gastrointestinal disturbances. It was also neither suitable for agriculture nor for domestic use, which meant that it was non-usable for human consumption nor did it allow aquatic life to be restored gradually. According to Govender (personal interview, 2013), the treated water was still ten times better than the untreated AMD water.

According to Govender (personal interview, 2013), the project to treat this basin commenced when the DWA upgraded an existing plant in Carletonville. In mid-2012 the plant was already operational and able to treat AMD. It is pumping the water from an underground mine system to the surface, and treating it to a “suitable standard and then discharging it into the environment”. The result is that decanting of AMD onto the surface and into the river system had stopped altogether and that now the water flowing down the river system was of improved quality as opposed to raw and untreated AMD. Govender also stated that the DWA had managed to “eradicate the decanting of raw AMD into the Krugersdorp Game Reserve”. In summary, Govender concluded that in the West Rand water had been flowing onto the surface uncontrollably up until the end of 2012 but once the DWA managed to get the plant going, it was able to stop the water before it flowed uncontrollably though the Krugersdorp Game Reserve.

The DWA also confirmed that decanting of AMD had stopped in the Western basin and that was done by upgrading an old Rand Uranium plant in Carletonville and pumping the drainage from the basin. “There has been an improvement of water quality in Tweelopiespruit into which AMD has been decanting” (Mouton 2013a). A long-term feasibility study that was conducted included identifying the damage already caused by AMD, as well as the aim that water should remain below the ECL. What is essential is that this long-term feasibility study also looked at the possibility of treating the water to drinking standard so that it could be used by industry and agriculture (Mouton 2013a).

Anthony Turton (personal interview, 2013) also agrees that in the Western basin the last decant that was reported was in September 2012. In his view, in 2013 the pH of the void ranged between 5.8 and 6.2 which was above the critical threshold of 5 and, therefore, makes it more alkaline. Anything below 5 means that uranium is soluble but when it is above 5, uranium precipitates into the void and no longer into the decanted water. A water plant has also been commissioned and is currently being tested to the regulatory protocol. Turton stated that once the regulatory requirements had been met according to the standards of DWA and formal authorisation granted, the pumps would be switched on and the void levels would be drawn down to the ECL within three years (Turton, personal interview, 2013).

Mariette Liefferink's view (personal interview, 2013) on the current state of the Western basin is more pessimistic. She is critical of the approach on the West Rand that after ten years it is now treated by adding lime to the water. When lime is added, the heavy metals drop out of the water but precipitate in the pipes. When water flows into rivers, it appears to be clear but the invisible toxins lie below. In the Sterkfontein Caves she said that the water levels were rising and some plants could not grow in the poor conditions. The water appeared to be clean but once lime was added, the heavy metals in the water started showing. Acid mine water had flowed into the Krugersdorp Game Reserve and Liefferink said that she had asked the management authority what had happened to the heavy metals found in the water but she had not received a clear response (Liefferink, personal interview, 2013).

3.5.2 The Central basin

Peter Kelly of the Cradle of Humankind explained that the Central basin extended from Durban Roodepoort Deep (DRD) mine in Roodepoort in the west to the East Rand Proprietary Mines Ltd (ERPM) mine in Germiston in the east over a distance of about 45 km and an area of 251 km^2. The whole area was interlinked and it could be treated as one void (Kelly, personal interview, 2013). He mentioned that up until 2008 the ERPM mine was still functional and that it was the only mine working in the whole central region. It was also the only mine pumping underground water out to prevent it from rising in the basin and to ensure that the mine could continue with its mining operations. During the pumping there was an incident when a gas bubble burst through the water and, as a result, people lost their lives. The National Department of Mineral Resources informed the mine that they had to make the necessary arrangements to ensure that this did not recur but they were unable to do so. Therefore, the pumping had stopped following this incident. Since September–October 2008 the water has been rising by an average of 300 mm a day.

Prof Frank Winde (Wait 2012b) from North-West University stated in 2012 that there was a wide range of possibilities to be explored in containing decanting mine water. He also mentioned that the mining industry and government have had enough time to look for a solution for AMD in the Central basin. This means that the issue was not treated as severe and should it become uncontrollable, then it is due to government's lack of attention and preventive measures.

Several observers predicted earlier that central Johannesburg and other parts of the Central basin would soon experience flooding of acid mine water. According to Mariette Liefferink (personal interview, 2013), the Central basin would have started decanting by September/October 2013.

Bashan Govender was questioned about the prediction that there would be water seepage in the centre of Johannesburg and about the situation in the Johannesburg CBD. He responded by saying that the buildings were at a higher elevation than what the mine water could reach. It means that the foundation structures of the buildings are above the level that can be affected by decanting water. According to him, the DWA had conducted geotechnical investigations to confirm that if the water did rise to the level that created a surface impact then the vulnerable construction components of these buildings would be above that level. He added that the DWA saw a greater risk in a situation when the water decanted into the river system and then affected the water systems such as the Kliprivier, Tweelopiespruit and the Blesbokspruit rivers in Johannesburg and the Vaal River. Developments in central Johannesburg, according to him, would not affect the Vaal Dam because the dam was situated west of the Eastern basin and therefore even if acidic water were to enter the river systems that originate in the Eastern basin, it would flow into the river system downstream of the Vaal Dam. This meant that the water from the Vaal Dam was still safe. Govender mentioned that water usage in the "downstream environment" was of concern, because the people living downstream and using it for agriculture, for resorts and for their purification works would be impacted (personal interview, 2013).

One of the focus points that serves as a barometer of AMD prevalence in the Central basin is the Gold Reef City theme park. It is located south of central Johannesburg next to the Apartheid Museum and not far from Soweto. The park was designed around a decommissioned gold mine that is now used for underground tours guided by former miners. It is important as it is one of Johannesburg's main tourist attractions. A media report on the Gold Reef City theme park being under enormous threat had surfaced on 14 March 2013 in the *Times Live* online. The article stated that “the Department of Water Affairs is racing against time to halt rising acid mine drainage in the central basin under Johannesburg” (Mouton 2013a). The article stated that the mine water was expected to reach the ECL by September 2013. According to a DWA spokesperson (Mouton 2013a), the department was not sure that it would be able to address this in the required time frame while excessive rain would also worsen the situation. This could have severe impacts on South Africa’s well-known historical museum, because if the theme park becomes flooded it will certainly have a negative effect on tourism (Mouton 2013a).

During the fieldwork, the interviewees were asked their opinions on how severe the threat of AMD to the Gold Reef City theme park was. In an interview with Bashan Govender from the national DWA, he was questioned on the media reports and the ongoing news that Gold Reef City was in danger of being flooded. His response was that “without a doubt, we are working on a very tight timeline” (Govender, personal interview, 2013). He also explained that the water has not yet reached the ECL. However, if it did reach that point, then it could start to react to underground water and the underground tours would not continue and there would be a chance that the tourist mine museum which is above ground at Gold Reef City would be flooded. From there it would flow directly into the Vaal River system. However, as long as it remained below the ECL, Gold Reef City would be safe. Govender said that Gold Reef City would start pumping out water from the mine shafts but would not be able to treat this water. According to him, at the time of the interview in February 2013, Gold Reef City Management ensured that an adequate process was followed so that the shaft did not become flooded and that the water level did not approach the ECL. Govender gave an important explanation for the situation and that is that Gold Reef City was also pumping surface water that accumulated after heavy rainfalls which was not yet acidic (Govender, personal interview, 2013). A significant portion of the water that is pumped into the Vaal River is therefore not a result of AMD, and does not carry the same levels of acid and sulphates.

In an interview with Anthony Turton, who has an ongoing relationship as a consultant with the Tsogo Sun hotel group (i.e. Gold Reef City owned by Tsogo Sun), he indicated that the hotel group announced early in 2013 that it would invest a further

R470 million in Gold Reef City, which is an indication of the group's confidence that the theme park had a long-term future. Turton emphasised the fact that Tsogo Sun had a very good understanding of the risk related to the environment. Turton stated that if the ECL had been reached in the Central basin, then the lower levels of Gold Reef City would be flooded but not the above-ground museum area. The park management would have to limit the level at which visitors would be allowed to go underground. Even in the worst case scenario, according to Turton, the decanting would not be as bad as that of the Western basin. Turton explained that implementation of the plans was behind schedule, because some environmental NGOs were challenging the fact that proper emergency measures were not used. "It is a case where law and reality aren't really applicable, it comes down to a judgment call of emergency over reality" (Turton, personal interview, 2013).

The media paid substantial attention already in 2012 to the measures taken at Gold Reef City to prevent decanting and to pump the mine water into the Vaal River system. In October 2012 the *Sunday Times* featured a media report about the effects of pumping treated acid mine water into the Vaal River system. According to the report (Jordan 2012: 10), the government has given permission for an emergency plan to be undertaken, to pump partially treated acid mine water into the Vaal River before it could flood Johannesburg and other areas on the Reef: "pumping it into the Vaal, a major source of water for South Africa's commercial farming sector will go ahead without a study of the potential impact on the river". It was expected that environmental groups would criticise this approach, because they had warned the government long in advance of the impending dangers (Jordan 2012: 10). Government is urgently trying to prevent the acid water overflowing out of Johannesburg's Central basin before it reaches the first known exit points, including the Gold Reef City mine museum (Jordan 2012: 10). The proposed solution was to follow a neutralisation process (i.e. to use underground pumps to pipe water from the Central basin to a treatment plant where it will be partially treated). The neutralised water will then be released into the Vaal River, where it will be diluted further with clean water from the Lesotho Highlands Water Project (Jordan 2012: 10).

According to Mariette Liefferink (in Jordan 2012: 10), this pumping of neutralised water could have a severe impact on the Vaal River. She also reiterated that this issue was known and has been stressed for a long time by academics and the public who have been directly affected since 1996 and from the decant that started in 2002 in the Western basin. The government therefore had sufficient time to identify alternative and more acceptable treatment and preventive processes (Jordan 2012: 10).

It is not only Gold Reef City that is the focus of attention but also the ERPM mine in Germiston which is used as a site for pumping mine water. Its priority status is very high and therefore the Minister of Water Affairs, Edna Molewa, has given the treatment plan for the Central basin “emergency status” (Jordan 2012: 10). It has been said that “essentially if the department does not implement certain remedial measures, rising subsurface acid mine drainage in the central basin may yield undesirable environmental and socio-economic impacts” (Jordan 2012: 10). Thus, pumping of the neutralised acidic mine water into the Vaal River will serve as a short-term intervention necessary for environmental and socio-economic protection (Jordan 2012: 10).

According to Bashan Govender (personal interview, 2013), on 8 January 2013 the pumping site in Germiston was handed over to the Group Five construction company but there was no infrastructure at the site. All that exists there is an abandoned mine shaft. Therefore, according to Govender, commissioning of this infrastructure will be extremely costly (personal interview, 2013). However, the mining company (not mentioned) that owns this shaft has made it available to the DWA to use for the project. This is an example where a mining company has partnered with the state to deal with the environmental challenge at hand. The mine shaft is directly adjacent to the mine water neutralisation facility where two pumps extract the acid mine water. The pumped and treated water is then discharged into a nearby river system. This is similar to what is happening on the West Rand near Krugersdorp where the water contains very high levels of metals and sulphates, and has a very low pH reading (i.e. high acid levels). In the treatment process some of this will be neutralised and some of the salts reduced. The process extracts 90 per cent of the surface harmful metals and brings the pH to a level that is suitable for the environment. The treated water is then discharged into the river system.

According to Govender (personal interview, 2013), the waste from the treatment process in the Central basin will be stored at the massive mine dumps in Johannesburg. With the treatment or neutralisation process, the waste sludge containing the iron and other metals, which are the by-products of the treatment or neutralisation process, is stored in the dumps while the water is released into the river system. As seen before in the definitions of AMD, NGOs and activists are wary of what happens with the MRA. The treatment process in the Central basin near Germiston will most possibly enhance the levels of harmful mine residues and when it is combined with extensive rainfall (sometimes acid rain, as mentioned by Anthony Turton), it can then create a new cycle of water contamination.

From the Gauteng provincial government's point of view, Peter Kelly (personal interview, 2013) also confirmed in March 2013 that measures were already in place under the DWA to commence pumping from South West Vertical Shaft in the ERPM mine in Germiston. However, he also cautioned, "I do not think this will be done in time, and this is the downfall, because it took so long for a decision to be made because of the serious amount of money that this is going to cost" (personal interview, 2013 (Kelly, personal interview, 2013). Unfortunately, there was also some infighting and politicking between the DWA and the mining company involved, namely DRDGold (the owners of ERPM). However, an agreement was reached at the end of 2012 and construction work commenced in January 2013. By June 2013, according to Turton, in the Central Basin engineering design and procurement had been completed and construction begun by some of the most skilled engineers in the country, and there was no cause for concern as the schedule for time and the budget seemed to be met (Turton 2013a). According to Govender, the agreement is that the treated mine water would be discharged into the local Blesbokspruit and would then flow into the Vaal River. The pH (and, therefore, the acid level) of the water would be brought to a neutral standard and the irons would be removed, though salts and sulphate may still remain evident. Sulphate remains the main problem in the water and will end up in the Vaal River (Govender, personal interview, 2013). Sulphate is a salt of sulphuric acid which causes the saline content of the water to be too high for both human consumption and for several agricultural products.

3.5.3 The Eastern basin

The situation in the Eastern basin is dominated by the Grootvlei mine in Springs. Its holding company was Pamodzi Gold, which had been provisionally liquidated and thereafter administered by the struggling Aurora Empowerment Systems (Plaut 2011). Aurora became notorious for the fact that its directors, including South African President Jacob Zuma's nephew, Khulubuse Zuma, and former President Nelson Mandela's grandchild, Zondwa Mandela, refused to pay the wages of about 700 Grootvlei miners for more than two years (Plaut 2011). In February 2011 the company also stopped pumping the underground mine water. The result was rising levels of water that infiltrated the surrounding mines such as Sub Nigel. Sub Nigel was also used as an underground training centre for miners but because of the rising water levels it had to be relocated to another mine (Naidoo 2011).

In April 2011 the South African Human Rights Commission (SAHRC) became directly involved in the AMD issue because of the Grootvlei fiasco. It expressed its concern about the detrimental environmental impact of inactive and decanting mines. In March 2011 the SAHRC established a Committee on Environmental Justice and Mining to advise the commission on issues related to mining and its impact on human settlements and the natural environment.

The SAHRC was concerned about the current and potential impacts of AMD on the Eastern basin and the Blesbokspruit. It raised both the potential human rights and socio-economic impacts as concerns. The commission understood that "mining activities have undermined the quality of water supplies and crops in the area and has negatively affected human health and the health of wildlife and ecosystems in the surrounding environments" (SAHRC 2011). As a human rights issue, the commission was concerned that AMD had the potential to threaten the realisation of a number of human rights in the South African Constitution, including the rights to food, water and an environment that was not harmful to one's health and well-being (SAHRC 2011).

By May 2013 the situation in the Eastern basin was regarded as critical. The main reason was that the liquidation of the Grootvlei mine had delayed progress. Negotiations were continuing to secure land and access to the mine.

The magnitude of the AMD potential on the East Rand is much greater than in the other basins. A simple comparison demonstrates this as follows:

Volume of AMD to be treated
Western basin – 27 Mℓ/d
Central basin – 57 Mℓ/d
Eastern basin – 82 Mℓ/d

Breach of the ECL if pumping does not commence
Western basin – already breached
Central basin – September/October 2013
Eastern basin – November 2014 (Cornish 2013).

According to Bashan Govender from the national DWA (personal interview, 2013), another potential socio-economic complication is that if this area is allowed to be flooded and the water reaches the dolomite formations in the area, it can affect the existing low-cost housing. AMD will not act as aggressively with dolomite and others say that it will. If the dolomite structures are constantly flooded and then again dewatered, it can weaken the stability of the dolomite. Differences of opinion about the potential impact still exist. Some argue that AMD will not act as aggressively with dolomite, while others say that it will. Govender (personal interview, 2013) was of the opinion that there was a good chance that the local communities would experience the impacts but scientific studies had not yet proven this.

The Eastern basin is thus the region where commercial mine pumping has continued the longest (until 2011), while in the Western basin it was stopped in 1996 and in the Central basin in 2008 (Cornish 2013). Ironically, the Eastern basin is now the one most problematic to commence with pumping as part of the government's AMD response. In the Western basin the capacity of the existing Rand Uranium plant has been increased by three-fold while in the Central basin the Trans-Caledon Tunnel

Authority, Group Five Civil Engineering and a host of contractors are involved in developing the biggest treatment plant in South Africa near ERPM's South West Vertical Shaft (Cornish 2013).

3.6 The Current Situation of Acid Mine Drainage and How Various Actors Relate to it

In the discussion so far reference was made to various role-players involved in some or other way with AMD. In this section their involvement is summarised, which will give an indication of their influence in the way AMD is dealt with or is presented to the public. The actors include the three spheres of government, NGOs, the media, the business community involved in mining, their consultants and specialists with a commercial interest.

Intergovernmental relations play a critical part in dealing with AMD. According to schedule 4 Part A of the Constitution (RSA 1996) the following are concurrent powers shared by the national and provincial governments relevant for AMD: agriculture, environment, health services, industrial promotion, pollution control, soil conservation and welfare services. In Part B the following are relevant municipal competencies: municipal planning, health services, and water and sanitation services limited to potable water supply and domestic waste-water systems.

Provincial government should be responsible for establishing a detailed inventory of all potentially polluting sites within their jurisdiction and for developing hazardous waste management plans. These plans should include waste reduction, recycling and reuse initiatives for both industrial and mining waste.

However, national government remains responsible for overriding provincial or municipal authorities where it becomes of necessity to "maintain national security, economic unity, essential national standards, the provision of minimum standards for the rendering of services or to prevent unreasonable provincial action which will be prejudiced or to the interest of another province or the whole country" (Adler et al. 2007: 36).

The national government's responsibility towards AMD is exercised mainly by the DWA and DMR. Before 2009, the DWA also included Environmental Affairs. The DWA is supported by the Trans-Caledon Tunnel Authority, which is directly involved in the Central basin but which is primarily responsible for managing the Lesotho Highlands Water Project. National government established the IMC in 2010 to coordinate the government's policy on AMD. The IMC receives support from a wide-ranging spectrum of research bodies. In the search for alternative long-term solutions, the DST also plays a supportive role.

At provincial level, the DMR plays an equally important part in monitoring and managing the AMD threat in the Vaal River system. As a parastatal, the Rand Water Board is the main water-providing body in the area of this study.

Several NGOs are actively engaged in the AMD field. Best known is the FSE headed by Mariette Liefferink. Earthlife Africa also has a monitoring project on AMD. NGOs follow their own specific approaches to the matter. Some concentrate on public awareness and use the media extensively or stage demonstrations and protests. Some use the courts for interdicts or judgments against mining companies to influence mining practices or water spillages. Some activists, such as Liefferink, also serve on government-appointed bodies and can, therefore, influence decision-making processes. According to Peter Mills, when asked about the role of NGOs and if he believed that they were making a contribution in assisting with the issues of AMD, he said that activists such as Mariette Liefferink have contributed and the water was cleaner now in places that were seriously affected (Mills, personal interview, 2013).

The media plays an important part in shaping public opinion about the current state of AMD. Specialised media such as *Mining Weekly* or *MiningNe.ws* report on the technical and policy aspects of the issue but, so far, have paid very little attention to the socio-economic impacts. The general media such as the *Sunday Times* make use of the comments of environmental activists or researchers and, as a result, the socio-economic aspects are more prominent. Social media are increasingly used and Anthony Turton's Facebook page is a good example of such use.

Stephinah Mudau from the Chamber of Mines (personal interview, 2013) mentioned that the ongoing media reports on AMD were slightly over-exaggerated and non-factual, and that they were not based on scientific evidence. She said that there were short- and medium-term actions, and that companies were doing their work and trying their best to address this issue.

The business sector is one of the most important stakeholders in the AMD issue. It includes the mining companies and most of them are also members of the Chamber of Mines. It also includes companies that are both involved in mining and rehabilitation such as Mintails. Associated with this sector are consultants and researchers such as Anthony Turton and specialists such as Peter Mills of the Cradle of Humankind or interest representatives such as AgriSA. In the next section the focus is especially on the mining sector.

3.7 The Mining Industry and Acid Mine Drainage

"There are 3 000–4 000 new mining operations taking place, but, how can we mine when there is no water" (Liefferink, personal interview, 2013; Liefferink 2013). This statement depicts the reality of issues that surround the AMD debates. The effects that it has on the environment and on surrounding communities can be immense if not addressed in time. This will have an overall impact on aims to ensure a sustainable future. Peter Kelly (personal interview, 2013) has similar views. He stated that "where there is mining, there is AMD". He added that where there was mining activity, human beings would always be involved. This meant that mining activities would always have some impact on people and the environment.

According to Mariette Liefferink (personal interview, 2013), the legacy of gold mining is that the mining companies do not include post-closure costs to their budgets but only the costs and impacts while mining is still in operation. Peter Kelly (personal interview, 2013) of the DMR and Stephinah Mudau (personal interview, 2013) of the Chamber of Mines are of the same view when it comes to this issue. They both believe that the issues that have stemmed from AMD are due to the legacy of mining but the problem lies in solving it today and who is responsible for the financial costs of this lengthy process. Liefferink (personal interview, 2013) estimated that about R2.2 billion would be needed to fund the AMD issue.

The Chamber of Mines as the representative of most gold mines exists to “serve its members and promote their interests in the South African mining industry” (Chamber of Mines of South Africa 2008). The vision of the Chamber of Mines is “to achieve a policy, legislative and governance framework, which is widely supported and which will allow the mining industry to convert as great a part of the country’s abundant mineral resources into wealth for the benefit of South Africa” (Chamber of Mines of South Africa 2008). On the question of how the Chamber of Mines was involved in the AMD issue and what its role was with regard to a way forward, Stephinah Mudau (personal interview, 2013) stated that the chamber served in government structures and there had been discussions about short- and medium-term solutions to AMD, while others had invested money in managing and pumping AMD water. Various mines had also made contributions, for example, Rand Uranium Mine in the Western basin. Mudau was asked to provide the chamber’s view on the issues of AMD, and she responded by saying that she believed that AMD was a legacy issue for the mining sector and should, therefore, be viewed from a legacy perspective. The best practice guidelines are in place, robust legislation is in place, government programmes are in place as well as feasible solutions to determine AMD problems.

Bashan Govender (personal interview, 2013) stated that mining industries dated back to the 1800s and that mining has been going on for over 100 years. He agreed that it tended to be a legacy issue that the government and the people faced. During the same time periods of active mining, water flowed into the mine system naturally.

Mudau (personal interview, 2013) emphasised the important contribution that the mining industry made to the South African economy and the GDP, and she did not believe that AMD limited this contribution. According to her, significant financial resources had been used to limit the impact and deal with the issues of AMD. However, she was of the view that mining companies had to be more careful if they were operating from a legacy perspective. Mines would now have to have a new approach to mining and there were laws with which they had to comply; for example, mining companies have to conduct an environmental impact assessment (EIA), as well as compliance monitoring. Social and labour plans are also in place. She also mentioned that mines were now bound by social, environmental and economic responsibilities, and were becoming more sensitive to environmental standards.

One of the most sensitive issues in the AMD debate is about who must take responsibility for the costs of AMD treatment and mine water management in general. What is the responsibility of the current and former mining companies? The procedures regarding the rules and regulations of mine closure are now vital, and new mining companies will have more measures to implement and responsibility with regard to the environment than previously. Mudau (personal interview, 2013) pointed out that there were different processes to mine closure now and that they started at the pre-feasibility stage but evolved over different stages of the life cycle of the mine. Section 43 of the MPRDA outlines the closure process of a mine, including “issuing a closure certificate” (Mudau, personal interview, 2013).

Mudau also reiterated that the National Water Act, 1998 (Act 36 of 1998) (NWA) and MRPDA (Act 28 of 2002) had the necessary safeguards in place that indicated to mining companies the correct procedures and regulations that they should follow. Mudau (personal interview, 2013) believes that sustainable development was already being promoted by the Chamber of Mines and that mines could not be granted a licence if sustainable development was not respected and promoted.

All interviewees for the present study were asked what the approach should be in cases where mines were abandoned, closed or mining companies were liquidated, while AMD from these mines contributed to the overall mine water problem, and environmental pollution and degradation. Mudau responded that the DWA should enforce the law and intervene if there were companies that did not comply with it.

Referring to several media reports in 2013 that stated that the DWA would take legal measures to ensure that the mining companies that were or are responsible for AMD would take ownership of the problem, Mudau’s response about its feasibility was that she did not know how it would be enforced or how the DWA would identify the responsible entities. In the past, according to her, there were better ways of dealing with legacies instead of “chasing after companies” (Mudau, personal interview, 2013). The fact remains that the majority of the mining companies responsible for the environmental damage caused by AMD were liquidated and no longer existed. How would these companies then be made liable for the damage? Mudau (personal interview, 2013) was of the opinion that it would become a task of the DWA, because “it is not legally possible” to make the companies liable. At the same time, according to Mudau (personal interview, 2013), the functional companies that were responsible for environmental pollution or degradation must pay according to what was stipulated in the NWA.

The opinion of Peter Kelly of the DMR (personal interview, 2013) was that individual mining companies were responsible for protecting individuals in the mine and the safety of workers. Mining companies should also remain responsible for the clean-up of AMD. Kelly also raised the point that the only problem was that many of the mining companies responsible for the pollution were no longer in existence or had been liquidated and could, therefore, not pay for the clean-up. This situation arises from past inadequate mine closure legislation. The current situation is that all new mining companies have to establish in advance a rehabilitation fund as part of their mine closure management plan. Kelly (personal interview, 2013) also mentioned that despite the fact that they were responsible for the clean-up, they also had a large part to play in the economic growth of the country and are a crucial industry.

The current procedure requires an extensive EIA process that is carried out by mining companies before they can receive a mining licence. Kelly (personal interview, 2013) also referred to the rehabilitation fund that all new mines must establish for the mine closure phase. Kelly (personal interview, 2013) observed, however, that despite these new measures “a community and a mine do not get along well together and people aren’t happy when there is mining activities that takes place where they live”.

3.8 Conclusion

Various aspects of AMD were discussed in this chapter in order to develop a broad overview or perspective of what the current state of affairs regarding AMD in the

Vaal River system is. The chapter presented the argument that such a perspective depends on how AMD is defined.

The first conclusion reached in this chapter is that two broad categories of definitions emerged from the research: one that concentrates almost exclusively on the underground mine water that is rising to the surface, and then becoming acidic and rich in sulphate salts, and the other category of definitions extends the first to include also acidic and radioactive water formed by surface interactions between acid rain and the mine dust on the tailing dams. The fact that the latter category is presented as an integral part of AMD is one of the most important conclusions of this study.

Conclusions about the current status of AMD in the three basins, mainly based on the first category of definitions, are the following:

AMD first appeared in the Western basin in 2002. It breached the ECL and affected the Krugersdorp Nature Reserve and the Tweelopiespruit. It also reached the Cradle of Humankind but so far has had a limited impact on the cave fossils and, therefore, on the tourism activities. Pumping of mine water is concentrated at the Rand Uranium mine and the water is treated. The quality of this treated water is a bone of contention among the different role-players. All of them agree that it is not yet suitable for human use but some refer to improved aquatic life, while others are concerned about the water coming from the mine residue areas.

In the Central basin the predictions about decanting in the Johannesburg CBD did not materialise and predictions about its impact on Gold Reef City also vary. At the time that this chapter was written, no surface decanting was present in this basin and a huge pumping project by the TCTA was in progress in Germiston which will contain the water levels below the ECL.

The Eastern basin – at the time when this chapter was written – was the cause for most concern, mainly because of the uncertain future of the Grootvlei mine in Springs. It is also the basin with the biggest volume of mine water to be contained. The main pumping activity is planned to take place at the No. 3 shaft but the

Grootvlei mine-ownership situation must first be resolved. Otherwise, the first decanting is predicted for November 2014.

In conclusion, depending on the AMD definition applied in the assessment, the underground mine water situation appears to be relatively under control but the water treated in the process is not yet suitable for human use. However, once the second category of definitions is applied, a completely different situation materialises, because many tailing dams or other mine residue areas are still in existence and pose a major threat to the quality of water in most of the river systems associated with the Vaal River. They cause additional types of water contamination and the response to them forms part of the discussion in the next chapter.

CHAPTER 4: THE POLICY RESPONSE TO ACID MINE DRAINAGE IN THE GOLD MINING SECTOR

4.1 Introduction

In Chapter 3 the nature of the Vaal River System and the significance of AMD in South Africa were discussed. The situation in each of the basins in the Witwatersrand was explained. AMD is caused by abandoned mines or those that became liquidated, and were no longer active and had to shut down their operations. Thus, the problem is not new but one that has been developing and becoming more severe throughout the years, especially since 2002, when there have been cases of harm to the environment. What is transparently evident thus far is that AMD is a concern and the parties concerned, irrespective of who remains responsible at this stage, have to ensure that consistent and adequate clean-up takes place so that the earth's resources can be preserved and the principles of sustainable development are abided by.

Government and the mining industry have established close ties over the years, because the mining industry was an essential sector that contributed significantly to the South African economy. What needs to be appreciated is that without this industry, economic development would be slow in the country and the possibility of it remaining stagnant would, to a certain extent, exist. Thus, the only means to address AMD and to achieve this goal is to focus on a way forward that includes a working relationship between the government and the mining industry. There have always been policies and laws in place to promote a clean and sustainable environment and ways to ensure that it stays this way. However, adherence to such laws and policies cannot always be ensured, and the impending AMD crisis is proof of this.

This chapter concentrates on the views of government and the measures that have been implemented to address the crisis at hand. Policies, and the various processes and possible solutions that are being followed at present are referred to. The TCTA and its role in the AMD issue is discussed, as well as the IMC expert report and its contents, which include the short- and long-term plans to address AMD in the three basins along the Witwatersrand area. The Gauteng Department of Rural

Development is also discussed with regard to its plans and implementation process for addressing AMD. Several government or policy documents are referred to in this chapter that discuss what should be done to mitigate the impending AMD crisis. What is evident in the AMD debate is that solutions are being pushed and ‘apportioning blame’ to the parties involved is no longer going to address or solve this issue. This chapter also looks at the roles of the private sector, that is, mining companies, and development and environmental consultants, which include civil society, NGOs such as FSE, and activists such as Anthony Turton, who have made immense progress and provides a way forward. These debates are discussed in this chapter.

The discussion is introduced by the existing legislative framework applicable to mining insofar as it deals with water management and its relevance to the different aspects of AMD.

4.2 Policy on Mine Closure and Water Usage

Legacies of mining activities in South Africa are faced with legal and financial responsibility to address the water-related impacts of many abandoned and ownerless mines (DWAF 2008a: 5). These mining companies have never been required to take on the legal liability for the damages caused (Fig 2011: 313). It however, remains extremely difficult to allocate the proportion of damage for which each mining company is responsible, given the fact that these companies are no longer in existence. Thus, there should be processes that are adhered to when a mine closes and this should be bound by law. When a mine closes, there should be assurance that the mine has a plan to implement, sustain, protect and preserve the water quality and quantity upstream and downstream of the mine after mine closure, and that those who are dependent on that water are identified and protected (DWAF 2008a: 5). Due to the fact that the responsible mining companies cannot easily be held liable “there should be clear demarcations in law about what liabilities the state should assume” (Fig 2011: 313).

According to DWAF (2008a: 6), when a mine closes, there are a few stakeholders who have to be considered and have different objectives with regard to the closure.

First is the mine, who wants to close with as little costs as possible and also to prevent post-closure costs. Second are the authorities whose objective is to minimise the exposure to short- and long-term risks which depend on state finance and implementation of a sustainable post-closure land-use plan. Third are the communities, who want to preserve a viable socio-economic structure after mine closure and to minimise the environmental impacts and pollution of water resources. Thus, the post-closure risks of mines must be minimised and the sustainability must be maximised. So, in actual fact, a mine closure plan must be sustainable over a life cycle of a mine (DWAF 2008a: 6). Several policies are significant for this study but AMD has emerged as a serious issue, because these policy stipulations and the legal framework are not practised in reality. For this study the following are important National Acts that have some consequences for AMD:

1. The National Water Act (NWA) (Act 36 of 1998)
2. The National Environmental Management Act (NEMA) (Act 107 of 1998)
3. The Minerals and Petroleum Resources Development Act (MRPDA) (Act 28 of 2002).

The NWA, which was administered by Department of Water Affairs and Forestry (now called the DWA) is the principal Act that governs water resource management in South Africa. The ‘polluter pays’ principle supports this act and has direct implications for the mining industry which closely relates to AMD. This stipulates that those who are responsible for producing, allowing or causing pollution should be held liable for the costs of clean-up and the legal enforcement.

The Act determines that pollution or degradation of the environment must be prevented or resolved. “The current perception that mine closure is unachievable needs to be addressed through technical as well as policy guidance. The implications of section 19 of the NWA that a mine be held responsible for its impact on water resources even after achieving certified formal mine closure from the Department of Minerals and Energy (DME), remains the basis for long-term water management employing a risk-based approach” (Hobbs et al 2008: 428). The lack of action to address the issues of AMD successfully on a timely basis will only harm the process of sustainable development. The TCTA is an important implementation instrument of the NWA and has also become directly involved with the AMD issue. It is a state-owned entity that has been established in terms of government Notice No. 2631 in the *Government Gazette* No. 10545 of December 1986. The notice was then replaced with Government Notice 277 in the *Government Gazette* No. 21017 of March 2000, which was circulated in terms of the NWA (TCTA 2011). The TCTA’s aim is to provide a sustainable water supply in the Southern African Region and is directly involved in South Africa’s Lesotho Highlands Water Project. TCTA provides advisory support to the DWA on the AMD project that has been implemented since 2010 (Govender, personal interview, 2013).

The NWA states that sustainability and equity are identified as central guiding principles in the protection, use, development, conservation, management and control of water resources. These principles recognise the basic human needs of present and future generations, the need to protect water resources, the need to promote social and economic development through the use of water, and the need to establish suitable institutions in order to achieve the purpose of the Act (RSA 1998a). National government, through the Minister of Water Affairs, is responsible for achieving the principles of this Act on behalf of the nation. The minister, thus, has ultimate responsibility for fulfilling certain obligations relating to the use, allocation and protection of, and access to, water resources (RSA 1998a). Section 3, public trusteeship of the nation’s water, states the following:

> (1) As the public trustee of the nation’s water resources the national government, acting through the minister, must ensure that water is protected, used, developed, conserved, managed and controlled in a sustainable and equitable manner for the benefit of all persons and in accordance with its constitutional mandate.
>
> (2) Without limiting number 1, the minister is ultimately responsible to ensure that water is allocated equitably and used beneficially in the public interest, while promoting environmental values.
>
> (3) The national government, acting through the Minister, has the power to regulate the use, flow, control of all water in the Republic.

Mining legislation in South Africa has existed for many years, and the MPRDA include very specific requirements for mine closure (RSA 2002).

One of the main objectives of the MPRDA that is related to this study is to

> give effect to section 24 of the Constitution by ensuring that the nation's mineral and petroleum resources are developed in an orderly and ecologically sustainable manner while promoting justifiable social and economic development; and ensure that holders of mining and production rights contribute towards the socio-economic development of the areas in which they are operating (RSA 2002).

According to section 3 of the MPRDA (RSA 2002), the State being the custodian of the mineral and petroleum resources, acting through the minister may:

(a) grant, issue, refuse, control administer and manage any reconnaissance permission, prospecting right, permission to remove, mining right, mining permit, retention permit, technical co-operation permit, reconnaissance permit, exploration and production right; and

(b) in consultation with the Minister of Finance, determine any levy, any fee or consideration payable in terms of any relevant Act of Parliament.

According to section 39 (3)(b)(i–ii) of the Act, which deals with the environmental management programme and environmental management plan, an EIA must be conducted within 180 days of the date on which he or she is notified by the Regional Manager to do so (RSA 2002). An applicant who prepares an environmental management programme or plan must investigate, assess and evaluate the impact of his or her proposed prospecting or mining operations on the environment, and the socio-economic conditions of any person who might be directly affected by the mining operation.

According to section 43 (1), issuing a closure certificate, the holder of a mining right remains responsible for any environmental liability, pollution or ecological degradation and the management thereof, until the minister has issued a closure certificate to the holder concerned (RSA 2002). Section 48 (1)(a) of the MPRDA states that closure objectives and how they relate to the mining operation and its environmental and social setting must be included in the environmental management programme (EMP) that is developed during the planning stages of the mining operations (RSA 2002). According to DWAF (2008a: 18), it is crucial that should there be any decisions regarding closure requirements and whether proper closure processes have been adhered to, it must be done together with government representatives who have the responsibility of protecting the environment, as well as social issues and any other affected parties.

The NEMA contains certain principles in section 2 that are applicable throughout the country to the actions of all organs of state that may affect the environment, and will apply together with all other appropriate and relevant considerations, which include the state’s responsibility to respect, protect, promote and fulfil the social and economic rights in Chapter 2 of the Constitution (RSA1998b). It must serve as a general framework within which environmental management and implementation plans must be formulated. It must serve as a guideline by reference to which any organ of state must exercise any function when taking any decisions in terms of NEMA or any statutory provision regarding the protection of the environment, and it must serve as principles by reference to which a conciliator under NEMA must make recommendations and, lastly, guide any law concerned with protection or management of the environment (DWAF 2008a: 41–42).

These laws and principles have been in the process of being drafted for years and the legislation that governed the mining sector remained the same, even as changes were made in government departments. The major concern then is why there is such a crisis and why is there so much uncertainty about who is responsible for the clean-up and the extensive costs regarding AMD. The fact remains that irrespective of what the law stipulates and what government’s role is as the trustee of natural resources – water and minerals – the problem of AMD and its effect on the water resources and the environment have become a factual reality.

According to Turton (2009), there is no clear policy on mine closure in South Africa that meets both human rights standards set in the constitutional Bill of Rights and the ‘polluter pays’ principle stated in the NWA. He further adds that the question is still unanswered as to whether mine closure is about mining, water resource management, human health, economic development, legal liability or purely ecological rehabilitation (Turton 2009). Fig (2011: 312) states that mining has always been relieved from the impact assessment requirement. Whereas, it is compulsory in other industries to obtain an environmental impact assessment for any new projects, in the mining industry there is an environmental reporting system that is managed by the Department of Mineral Resources and mining is not open to a more rigorous regulation by the Department of Environmental Affairs. Thus, there is a serious shortfall in these systems, because they only control individual sites and do not examine the accumulated impacts on a region of new development (Fig 2011: 312).

4.3 Governance

To understand the extent and the possible consequences of the issue of AMD and of regulating pollution caused by the mining industry, according to Fig (2011: 311), one needs to question whether the people of South Africa have been treated fairly by the government’s current legislation and administrative practices. The prime issue – that was also mentioned in Chapter 2 about the relationship between the mining industry and government – is that for over a century the economy has placed most emphasis on the mining industry and put it at the forefront, even allowing environmental and public health protection costs to be made the responsibility of the taxpayer or the state (Fig 2011:311). The state had not addressed the environmental impacts of the mining industry during the apartheid years. Even though current mine owners are placed under tremendous pressure, the mine owners who must take most of the responsibility are those who profited from South African gold and uranium during the “boom years” of mining (Fig 2011: 311). The ownership benefits for mining companies were great during the productive cycle of gold mining and those companies should take the primary responsibility today for the environmental impact (Fig 2011: 311).

According to Fig (2011: 312) post-apartheid governments had observed a common interest between the political elite and the mining industry, and instead of pushing for a balance between growing the economy and protecting the environment, the new laws try to magnify opportunities for new entrants in the mining industry to address the racial economic inequalities of the past, with environmental protection being a barrier to these opportunities.

Being aware of the evolution of water governance and AMD management in South Africa allows one to understand the problem that the state faces in being able to manage liabilities and successfully implement new legislation. According to Hobbs et al. (2008: 422), in the cases of mines that closed in the period 1976–1986 the state and the mine owners have to share the responsibility of the post-mine closure costs. However, in the case of the mines that closed after 1986 their owners would remain responsible for all post-mine closure costs. Thus, mine owners had to comply with the EMP for mines that were closed, taking into account the effects that their mining activities have had on the environment (Hobbs et al. 2008: 422).

Interviews were conducted with people who are directly involved with some of the stakeholders to determine their views about governance matters. As a representative body of the mine companies, the Chamber of Mines is a key role-player in ensuring that the mining sector is properly governed. Stephinah Mudau (personal interview, 2013) said that the Chamber of Mines did not allow mines to be granted a licence if the mine was not sustainable or justifiable. She said that the laws that were now in place made that industry sustainable and that the Chamber was already promoting sustainable development in all its operations.

Peter Kelly from the DMR (personal interview, 2013) is of the opinion that government should support the mining industry, but if it could not do so and mines did not have a big enough rehabilitation fund then the government should assist. According to Fig (2011: 313), DMR should oversee post-closure plans of all mine owners and the state through the IMC or the DMR should form a larger fund for addressing the problem of AMD.

Bashan Govender from the DWA (personal interview, 2013) stated there was a two-fold governance approach to how the state had reacted to AMD. The first was that mining companies were accountable and should solve the problems of AMD on their own. The second approach was that government has, since 2002, been the custodian of water resources and water in South Africa and, therefore, water resources could not be owned by any individual person. He added that water in this country belonged to the state and therefore to the people of South Africa. Government was just the caretaker on behalf of the state and had to protect the water resources and should intervene to deal with AMD in keeping the water clean. In accordance with the NWA, the minister had to take responsibility to ensure protection of, and access to, water resources (RSA 1998a). Govender (personal interview, 2013) added that this was what the DWA had done, but private companies had also exhausted the wealth in the country and had a huge role to play in assisting to address the clean-up of AMD. Govender stressed that the DWA was strongly considering how the mining sector would take responsibility, keeping in mind that this was a legal process and would result in a lengthy time frame (personal interview, 2013).

The ‘blame-seeking’ debates tend to form constant discussions and constant media reports as to who is responsible for this and how action will be taken to ensure the responsible party is brought to justice. An article that appeared in *Times Live* online (Mouton 2013b) states that “DWA will lay criminal charges against all mining companies – new and old – that may be responsible for AMD problem in Gauteng. The department apparently drew up an ‘urgent report’ which will be submitted to the Minister of Water Affairs, Edna Molewa which will include a plan of action”. According to this article, DWA is going to try and trace the ownership of the mines since the 1940s and to determine who is responsible for polluting the water in the area and how they can be held liable.

Turton indicates that a wide range of technologies have been tested and this allows for a robust choice to be made with a different set of cost-benefit options that are defendable to the wary public who pays tax (Kolver 2013). He says that there are two distinct business models. The first is the State Option whereby the taxpaying public will be contributing towards the bill which includes the cost for neutralisation of AMD using the High Density Sludge (HDS) technology. The second option is the Polluter Pays Principle Option, which is one-third of the cost, while the mining industry will consolidate tailings facilities and bring mine-impacted land back into safe public use over the next 20 years (Kolver 2013).

With the government trying to bring the mining sector to the forefront and ensure legal steps are taken so that the industry can pay for the clean-up of the damages that have been caused, much confusion exists in South Africa with regards to the roles and responsibilities between the government departments, and who should take on what roles. In the past, confusion existed between the Department of Mineral and Energy (now called the Department of Mineral Resources) and the Department of Environmental Affairs (DEA) with regard to management of mining waste. Both these departments have emphasised the specific requirements on mines before a closure certificate is granted, and the main requirement is a compulsory environmental management plan. Co-operative governance has not been very effective in protecting the environment against the negative impacts of mining waste (Oelofse et al. 2007: 7). Peter Kelly from the Department of Mineral Resources (personal interview, 2013) does not see AMD as an impending crisis. He added that DWA was taking the lead in addressing AMD and the team had developed a strong enough voice but at times did not get through to the people who had a strong enough voice.

At this stage the most pertinent governance issue in relation to AMD is therefore to determine who must take responsibility for the management and cost implications of all the post-closure problems, of which AMD is an important, but not the only, component. Moreover, in view of the latest experiences with AMD, governance in the form of preventive measures are becoming increasingly important, in the form of EIAs and budgeting for eventual mine closures.

4.3.1 Possible treatment technologies and problems at this point

Thus far, no permanent or sustainable solution to the problem of AMD has been found. Neither has adequate monitoring procedures to the problem been introduced. Workable measures were not taken initially when the AMD problem first developed and in some instances have still not been carried out. A lack of resources is sometimes blamed for an inadequate response to groundwater in South Africa (Cobbing 2008: 456).

According to Cobbing (2008: 457),

> South African legislation governing pollution of water and the environment is both comprehensive and clear in the legal obligation to curb and remediate such pollution. It is true that the legislation is relatively new, but the obligation to act in a precautionary manner even where a pollution problem may not be fully understood remains. Whilst South African government has been accused of dragging its feet when it comes to enforcing compliance by the mining industry with the new environmental standards, in the experience of the author, South African government departments have allocated considerable time and resources over several years to try to resolve the Western Basin AMD problem.

Thus, it is argued that a shortage of skilled personnel, money or official sanction in the form of legislation seem not to have been limiting factors in addressing AMD in the Western basin, where it first appeared in 2002. The absence of a “comprehensive hydrological response” and the time it took to implement partial solutions tend to be more than just a problem of shortage of skills and resources (Cobbing 2008: 458).

The following are possible reasons for these problems as identified by Cobbing (2008: 458):

> The relatively low profile of groundwater in South Africa – this is the case because almost two-thirds of the country’s population depends on this resource for their domestic water needs. The privatisation of water data – a large part of South Africa’s leading groundwater lies outside of large, state-affiliated organizations and a large part of this work is contracted out by the state to the private sector. The lack of specific expertise at the decision-maker level – many of the efforts that are set out to address the Western basin have been managed by individuals with specific expertise in groundwater. There are cases where expertise exist, however project coordination and the correct input to mitigate the problem are lacking. Inadequate links between South African organisations – for addressing

problems such as the AMD in the Western basin relies on high levels of cooperation between stakeholders but such cooperation is not yet apparent in this particular case. A reluctance to make use of international expertise or knowledge – management of water resources can be better facilitated in southern Africa if it is understood as an active dialogue between groups known as "Actor Clusters".

Cobbing's proposal suggested that each cluster could be subdivided into three main elements. The clusters are as follows:

1. The state authorities – legislature, executive and judiciary
2. Society – civil society, the economy and the natural environment
3. Science – natural sciences, social sciences and tertiary educational institutions which provide human capital (2008: 458).

These clusters should "act in direct equilibrium with each other" (Cobbing 2008: 459). This means that project managers need to focus on collaboration and communication with other stakeholders in order for a process to go accordingly. Government needs to ensure that they use the technical and scientific understanding that is available in formulating policy (Cobbing 2008: 460). The business and mining community must have clear signals and guidelines that are necessary from both government and from specialist scientists to facilitate long-term planning.

According to Govender (personal interview, 2013), the government's approach to the Western basin was not ideal but the DWA was trying to ensure that the harmful metals were pulled out by reducing the iron concentration and reducing it to drinking water standards. He added that it would make sense to treat the water in the Western basin to drinkable water standards if there was a community that could benefit from this, as it would be costly to do so otherwise for no purpose. He said the department has realised that there was an environmental impact of water that had a low pH and high iron sulphate and this was affecting the ecosystem. The department was convinced that it had to contribute a significant amount of input, otherwise it would negatively affect the aquatic life in the water systems. He stated that this was the same principle used in the Central basin where the rising water levels in the mines had increased seismic activities around Johannesburg. The department was convinced that it could not allow seismic activity to increase:

> We recognise the challenge of AMD, we recognise what we are doing just to manage the programme in the short-term approach but we also recognise that this is a water-stress country, water down is a substantial amount that could be used to augment water supply. The Vaal River system is in high demand for industry and agriculture, so we should see this as an opportunity and not a threat. In 2012 a feasibility study was done, in 2013 we had the approval to build it up, so there are short-term interventions for how and what they will treat this water with (Govender, personal interview, 2013).

Govender (personal interview, 2013) further added that “if it means that we have to bring the water to a standard where we treat it and drink this water, then the taxpayer will have to pay”.

The Strategy Steering Committee of the Vaal River Reconciliation Strategy considered two options: (1) the limited treatment option and (2) the desalination and re-use option. The limited treatment option supposes that the water from the East, West and Central Rand Mining basins will be pumped to the surface and neutralised. The water will then be discharged to one of the Vaal River tributaries and will flow into the Vaal Barrage (Van Wyk, Rademeyer & van Rooyen 2010: 4). Shanna Nienaber from the DST, formerly from the CSIR, (personal interview, 2013), explained how the water was neutralised and put into the Vaal Barrage. If AMD entered the Vaal River system it would be detrimental. The DWA have been careful that this would not be the case, “it is one vicious cycle, the problem came through mining and legislation of government at the time and now we have inherited this problem, that is why we are trying to get the mining sector involved and identify how they can assist with this problem” (Govender, personal interview, 2013).

The second option also supposes the same process, but once desalinated, it will possibly be used for industrial purposes or as drinking water in Gauteng (Van Wyk et al. 2010: 5). It is evident that when this strategy was planned in 2010, it was concluded that despite this being a possible process, only to neutralise the AMD and then release it into the Vaal River, it would lead to future complications for the system. From the fieldwork that was conducted, with the various interviewees, feedback on short-term solutions was discussed. Peter Kelly (personal interview, 2013) and Bashan Govender (personal interview, 2013) explained the treatment that was currently taking place and the plans for the basins that were not yet affected.

Shanna Nienaber from the DST (personal interview, 2013) discussed the short- and long-term solutions to AMD. The information she provided comes from the IMC report. The short-term solution includes that of a high-density sludge management (HDSM) process, this is a partial neutralisation process where lime is added to the water and the water that is released has a lower metal load. She explained, however, that this did not mean that the water was clean, it could still have high salt levels. The long-term solution included looking at all possible options. This included how the problem would be managed, how the water would be purified and at what levels the water would be purified, would this be at a drinking water level or an ecosystem health criteria quality, and, lastly, what technologies would be used to do this (Nienaber, personal interview, 2013).

Nienaber stated that three coalitions had emerged around the question of how to address AMD. The first was the dominant coalition which was comprised of government departments – DWA, DMR and DST – and their approach was to “play it safe”. From 2010 until now their viewpoint was that they could no longer wait and that they had to act in the short term. Based mainly on the recommendations of the IMC, they commenced with pumping of underground mine water and high-density sludge management or chemical treatment of the acid water as an immediate short-term solution. The long-term technological solutions were still investigated by advisory private companies such as Aurecon (discussed in section 4.4), and a group of scientists who were co-opted to assist the government with its decision-making. The second coalition promoted the view to “do nothing”, because they were convinced that the water would eventually neutralise itself. The third coalition included those who said, “hang on, let’s talk about it”. It consisted of NGOs and the scientists excluded from the government group. They felt that the IMC was an exclusive process and that they could have had some ideas to assist in finding solutions and should have been included (Nienaber, personal interview, 2013).

In November 2008 the DWA held a meeting which discussed a way forward in managing AMD and which brought about the IMC (Nienaber, personal interview, 2013).

4.3.2 Inter-Ministerial Committee on Acid Mine Drainage

4.3.2.1 The Inter-Ministerial Committee Expert Report

The IMC report of 2010 prepared by a team of experts working in a wide spectrum of disciplines relevant to understanding the nature and implications of AMD serves as a vital and crucial source of information for this study. A team of experts that included directors general of Mineral Resources and Water Affairs were selected to advise the IMC, which also included the Ministers of Mineral Resources, Water Affairs and Science and Technology, the Minister in the Presidency and the National Planning Commission. Their focus was on AMD in the Witwatersrand gold fields (Coetzee et al. 2010: 2). The DWA received funds from the National Treasury for the purpose of implementing measures to pump underground mine water to prevent it from reaching the ECLs, to neutralise and remove metals from AMD and to initiate a feasibility study to address the medium- to-long-term solutions (DWA 2012: 1–2).

This expert report referred to international and local research literature on all aspects of AMD which include its formation, control, management, treatment and impacts (Coetzee et al. 2010: 2). The report concluded that there was thus an overall understanding of the AMD issues in South Africa. The experts' view was, therefore, that there is ample information available to make decisions that relate to mine water, its potential impacts, management strategies and treatment technologies in the Witwatersrand gold fields. The issue of AMD is said to have an impact in a number of areas in South Africa. These include the Witwatersrand gold fields, Mpumalanga (Carolina), KwaZulu-Natal coal fields and the O'Kiep copper district. The Western, Eastern and Central basins of the Vaal River system are regarded as the main areas of concern. These areas are said to require immediate action because sufficient measures had not been taken to manage and control the problem. The Mpumalanga coal fields have been noted as a vulnerable area where the impact of mining on the freshwater sources in the upper reaches of the Vaal and Olifants River systems is of serious concern. The severity of the environmental impact in other mining areas of the country needs more information such as monitoring and assessment of risks (Coetzee et al. 2010: 8).

Several risks related to the flooding of the mines in the priority areas and the subsequent decant of AMD to the environment have been highlighted. These risks include risks resulting from flooding of the mines and risks due to decant of AMD to the environment. An approach has been adopted to manage these risks in the priority areas. The approach includes decant prevention and management, reducing the rate of flooding and the eventual decant volume (reducing the volume of water to be pumped and treated), and water quality management (there is a different technology to deal with this) (Coetzee et al. 2010: 37).

During the interviews conducted with the participants, they were asked how they viewed the IMC report and whether this report was sufficient to deal with the extent of the AMD issues. They had various responses. Peter Mills from the Cradle of Humankind Management Authority believes that the IMC addressed a small field of AMD (Mills, personal interview, 2013). Bashan Govender from the DWA mentioned that in late 2010 the entire DWA was informed by its minister about the impending AMD crisis and that is how the IMC came about (personal interview, 2013). In 2011 the recommendations stipulated in the report were accepted by the Cabinet as government policy, which consists mainly of pumping of the mine water and its initial treatment (i.e. sludge management). Govender regarded it as sufficient, although it does not mean that the water is already appropriate for human use (personal interview, 2013).

According to Shanna Nienaber (personal interview, 2013), people who have worked on the IMC report had the best intentions, are highly qualified and have a very detailed understanding of the situation. However, when compiling the report they were constrained by time and as the technical experts on the issue they may not have recorded the thought processes that underlie the recommendations. Nienaber observed that the NGOs were not part of the IMC or the technical task team and that they had much criticism. They believed that high-density sludge management, for instance, was not a solution, because the treated water was not purified. However, the response from the team members was that something had to be done rather than nothing at the time. According to Nienaber (personal interview, 2013), there was thus miscommunication between the IMC and their task team, and the rest of society.

4.3.2.2 The options identified in the report

When the report was compiled in 2010 the status situations in the three basins were as follows: the Western basin was fully flooded above the ECL and has been decanted to the surface since 2002. In the Central basin, pumping had ceased at most of the mines and the water level in the basin was rising. In the Eastern basin, pumping was taking place only in the Grootvlei mine (until 2011) so that the water could be maintained at around 700 m below surface. In response to this situation, the report identified four objectives, namely (1) management of flooding and/or decant, (2) ingress management, (3) water treatment and (4) monitoring. Options were identified under each objective. A discussion of these options follows, as well as their advantages and disadvantages. All four objectives are derived from the IMC report and are taken from Coetzee et al. (2010: 55–61).

The first objective is to manage the flooding and/or decant of the basins. The first option was to pump water and to keep it well below the ECL. This option could ensure environmental protection but it would be financially costly. The second option was to pump water from a level shallower than the ECL and, therefore, closer to the surface. This could lower the cost of pumping but would more likely place the environment at risk. The third option was to allow the decant in areas where younger surficial cover rocks acted as a seal above the mine void, which would avoid pumping costs. However, this option could lead to seepage and secondary decant points developing; water could rise into dolomitic layers causing groundwater contamination and sinkhole formation, and it does not allow for seasonal balancing of volume for water treatment. The fourth option was to construct a tunnel to create an artificial decant channel. It would not involve pumping costs and would ensure that the decant occurred in a controlled process. However, capital costs of the tunnel would be high, the environment would not be fully protected unless the tunnel could be constructed below the ECL and it did not allow seasonal balancing of water treatment volumes. It would also involve long-term maintenance costs and there was a risk of tunnel failure. The fifth option was to provide a tunnel to a remote pumping station to reduce pumping costs. This would allow for the location of the abstraction point for water according to the optimal location for a treatment plant, but would limit access to the underground workings and complicate construction. It did not remove the requirement to pump water. Given the focus of this study, one can conclude that the options stipulated under this objective fail to highlight the human element and the impact that AMD can have on socio-economic development if this option were to be implemented. If costs are lowered, then the environment stands the chance of being at risk, the actual risks to the environment are also not indicated. The impact that this will have on people and communities that live in surrounding areas are not discussed, nor are the health implications that could stem from the decant (Coetzee et al. 2010: 55–56).

The second objective is ingress management to prevent mines from being filled by surface water. The first option was to seal the areas of surface ingress such as riverbeds and old mine workings, for instance. This option can reduce the long-term water management costs, lower the water volumes and may result in more options for management and for some of the projects being implemented by mines. The disadvantage of this option is that some of the projects may require high capital costs. The second option is to abstract clean water from overlying aquifers before it enters the mine void. This option can keep clean water clean, reduce ingress and provide a source of clean water to local users. However, it will need to be adequately managed in dolomitic areas to prevent subsidence. This objective gives the option to have clean water, but whether it is of drinkable quality is not indicated. Households need water for hygienic purposes, but also for drinking and cooking purposes. There are many users that need access to clean water, such as the tourism sector, Eskom for electricity and agriculture. Thus, clean water can be used and needed for various crucial purposes (Coetzee et al. 2010: 57).

The third objective is water treatment. The first option is to neutralise and remove the iron. This is the lowest-cost option. It can remove the heavy metals and can be implemented within a short period. The pre-treatment stage is necessary for the most advanced treatment methods and it can return conditions to those that existed during active mining. However, this option does not fully address the problem of salinity and the treated water will not be suitable for all the users who need water, be it at household level, for tourism, agriculture or business. Furthermore, this option will require facilities for sludge disposal. The second option is desalination. This option is proven with a limited number of commercial biological sulphate removal, membrane treatment and chemical precipitation plants. It produces clean water that can be used for any purpose, including for drinking. The salts can be removed completely from the river system and it may produce saleable by-products that could offset some or all the costs. However, there will clearly be high capital and operating costs involved and not all the technologies have been tested fully. The membrane processes can have high costs and there will be a need for waste management (Coetzee et al. 2010: 57–58).

The third option is to discharge water without treatment. This will not cost anything, but there will be serious effects on the downstream environment and this will increase salinity of downstream river systems. One can predict that this option does not account for the human element. A large number of people who depend on this water for their own use or those living in the surrounding areas will experience the effects of the polluted water, such as health implications. The fourth option is *in-situ* treatment which does not require a fixed plant and relatively clean water can be abstracted from the mine void. Active and ongoing operational personnel will be required but permanent presence on site is not required. This option will require chemicals, operations staff, intermittent field maintenance, electrical power and low frequency monitoring. However, it will also require a system with good mixing characteristics and enough points of access to the void water, which is not the case in the Witwatersrand mines. There will also be relatively inefficient mixing, which requires large input of reagents. The fifth option is for passive treatment, especially the use of natural wetlands through which the polluted water must move and be filtrated. This is seen as a low-cost option and moderate capital investment with periodic reinvestment to replace depleted wetlands media. It is a self-sustaining process that requires periodic maintenance and intermittent monitoring. This may require replacement or supplement of materials at low frequency. The natural energy sources of gravity flow, solar and bio-chemical energy can be utilised and it will require little intervention. However, this option creates contaminated areas in treatment systems and is generally regarded as being unsuitable for the large volumes and poor quality of the water expected from the Witwatersrand. It will require extensive monitoring to evaluate success and an additional carbon energy source for bacterial processes. The treated water will be of poorer quality and be more variable than the other options (Coetzee et al. 2010: 58–61).

The fourth and last objective is monitoring. The first option is for no monitoring to take place, and this has low costs, but there will be no way to evaluate the improving or deteriorating conditions and no early warning information will be available. The second option is to maintain the current monitoring regime. It will involve no extra costs but the current regime has proven to be inadequate to assess the extent and degree of problems and there will be no early warning capacity. The third option is improved monitoring systems that will allow the assessment of problems and solutions, and will provide early warning capabilities. The disadvantage is that it will mean higher costs and additional strain will be placed on resources unless monitoring activities are well sourced (Coetzee et al. 2010: 61).

An evaluation of the objectives and options identified in the IMC report to address the water treatment in the Witwatersrand area shows that the report did not use sustainable development considerations as one of its criteria for determining the approach to AMD. In the process of considering all the options, their advantages and disadvantages were identified in a technical and financial sense but they did not include that of preserving water as a natural resource for human use and tend to only look at how to address the issue in the short term. The possible risks to the environment are indicated under some of the options, but these risks are not discussed in detail as to their possible impact on the environment. The socio-economic impacts are completely absent from the identified disadvantages.

In Chapter 5 of this study, the socio-economic impacts are discussed in detail. However, for the purpose of illustrating why the failure of the IMC report to highlight them is so important, some of the health implications are mentioned here. Mariette Liefferink is an activist who tends to focus more on the social impacts of AMD, and how it affects people and their health. She also looks at the environment and believes that the damage caused could be irreversible. According to her, all wetlands in the Witwatersrand contain heavy metal contaminants. Leukaemia is one of the health impacts that are known to arise from this (Liefferink, personal interview, 2013). The health impacts of uranium particles being inhaled can have a detrimental impact on human beings. Highly soluble uranium compounds may remain in the alveoli. On the one hand, soluble uranium compounds dissolve and pass across the alveolar membranes into the bloodstream, where they may exert systemic toxic effects, while, on the other hand, insoluble particles may form in the lungs for years and can cause chronic radiotoxicity expressed in the alveoli.

After the IMC expert report, in 2011 a multidisciplinary team was requested to undertake a feasibility study of the technical options in the report for the long-term management of AMD. The team had to make a careful assessment and integrate all possibilities for the use or discharge of raw, neutralised or desalinated AMD that would meet the objective of reducing the salt load in the Vaal River system to acceptable levels and that would not have an unacceptable social or environmental impact (DWA 2012: 7). The concern is that this assessment and integration of options were not included in the IMC report.

4.3.2.3 Recommendations made by the Inter-Ministerial Committee report

In the IMC report the team of experts included eight recommendations based on the possible options that were discussed in section 4.3.2.2 of the present study. The team of experts was of the opinion that “sufficient information exists to be able to make informed decisions regarding the origins of the mine water, potential impacts, management strategies and treatment technologies” (Coetzee et al. 2010: 85). These recommendations were adopted as the framework of the government policy on AMD. They are discussed below as they were identified in the IMC report. The recommendations are included here as an indication of the public policy dimensions that should be evaluated in terms of the sustainable development principles discussed in Chapter 2 of this study. The discussion relies on Coetzee et al. (2010: 88–92).

The first recommendation was that it would be necessary to pump water from the mine voids in the three basins to prevent decant and to ensure that water levels were maintained at or below the ECLs. In the Western basin, the ECL was to remain at 150 m below the decant level to ensure protection of the dolomitic groundwater resources in the Cradle of Humankind World Heritage Site. In the Central basin, the water level had to be maintained at least 150 m below surface at the South West Vertical Shaft in Germiston. It was further recommended that a level of 50 m below this should be maintained in order to protect Gold Reef City which attracts about 3 000 tourists per day. Pumping from a deeper level would be necessary to protect the underground resources of interest to newcomers in the mining industry in the affected area. The basis for this was to protect the dolomitic aquifer to the south of Boksburg. In the Eastern basin, the ECL is to be 400 m below surface measured from the likely decant point at Nigel, in order to prevent the rise of the mine water into the overlying dolomitic aquifer (Coetzee et al. 2010: 88–90).

Construction of new pumping infrastructure was recognised as urgent for the Western and Central basins in order to manage the flooding of these basins and to remove the risks associated with the uncontrolled decant of AMD. In the Eastern basin, the pumping was to be maintained to allow access to underground workings. It was added that state assistance must be continued and maintained in the Grootvlei Mine. It should be noted that the government's immediate response in 2011 when pumping at Grootvlei was terminated, was that Finance Minister Pravin Gordhan allocated R225 million over a three-year period in the national Budget to deal with AMD, and more than half of it was earmarked for the Grootvlei gold mine on the Eastern Witwatersrand basin (Mouton 2013b).

In the national budget speech in 2012, Pravin Gordhan set aside R422 million for short-term interventions to deal with this problem, with a total of R2.2 billion to solve the AMD problem (Mouton 2013b).

The second recommendation was that of ingress control to reduce the rate of mine flooding and the water volumes that had to be managed. Research conducted by the CGS identified areas in the three basins where measures were to be implemented to reduce the ingress of water into the mine void. This will also reduce the volume that needs to be pumped from the mine void and treated. From this water, management costs will be reduced in the medium to long term. In addition to preventing ingress, prospects have been identified in the Eastern basin where clean groundwater that enters the mine void but runs the risk of becoming polluted can be abstracted before it enters the underground workings. It could thus become a source of clean water. The recommendation was made for it to be fully looked into and implemented. To implement ingress prevention measures could take years to complete, because it would include applications for a water use licence and concluding agreements with landowners. Thus, during this period, it would be necessary to pump and treat a larger volume of water than after the measures have been implemented (Coetzee et al. 2010: 90).

The third recommendation is water quality management. The report observed that water pumped from the mine voids would at first be of poor quality and would need to be treated before it could be discharged into the river systems or utilised. The treatment could be limited to neutralisation and the removal of metals from the water before discharging it into the river systems. The outcome of this is that it would lead to the same conditions as those established during the period of active mining. This is not a long-term sustainable solution due to the fact that the salt loads in the affected river systems are already high. In the medium to long term, removal of the saline mine water from the river systems must be taken into consideration as a reduction of the pollution source. In the extreme long term, according to the report, it is possible for the water quality in the mine void to improve as oxygen is not included from the flooded voids and contaminants that are present are flushed from the system. If this is the case, water levels may be allowed to recover to their natural levels, as long as this does not lead to uncontrolled flooding issues or unintended geotechnical impacts (Coetzee et al. 2010: 90).

The fourth recommendation was about monitoring. The success of the suggested programme can only be verified through a detailed monitoring of the water in the mine voids and the affected environments. The investigations conducted when identifying treatment options have also found several shortcomings in the present monitoring of water quality and the flow in the areas downstream of mining activities. Thus, these shortcomings need to be acknowledged and solutions need to be provided in order for the medium- to long-term strategies to be optimised for AMD management, especially where there are impacts on the Vaal River system. In the short to medium term, seismic events need to be monitored. It can be identified whether the immediate surroundings of mining areas will be prone to seismic activities or whether they are moving away, which will, in turn, imply that there might be a potential risk of geological activities at some distance from the mining areas. It is further stated that the information gathered over time would be useful for microzonation studies. This will also show the changes that occur in the seismic risks to which the infrastructure within the urban areas surrounding the Central basin will be exposed. As part of this recommendation, a multi-institutional monitoring committee was proposed to conduct the implementation of the required monitoring and assessment programmes. The committee can observe changes in the quality of mine water and this may impact on the future management strategies (Coetzee et al. 2010: 91).

The fifth recommendation was directed at addressing other AMD sources. The flooded mine voids are not the only form of AMD in the Witwatersrand. The tailings and other waste materials that are formed by mining are also major sources of AMD. But it is stated that the absence of comprehensive flow monitoring networks in the priority areas prevents quantification of the impacts. This also brings about the need for improved monitoring. Continuous studies and counteractive measures will be vital to reduce the impact of such AMD sources (Coetzee et al. 2010: 91).

The sixth recommendation was that further research was required to identify and optimise sustainable solutions in the medium to long term. Even though measures must be implemented in the short term, according to the report, there are still some areas of uncertainty where solutions need to be found in order for sustainable medium- to long- term solutions to be implemented (Coetzee et al. 2010: 92).

The seventh recommendation was to investigate the feasibility of an environmental levy on operating mines. This includes investigation of the feasibility of an environmental levy that needs to be paid by operating mines to cover the costs of the legacies of past mining needs, including AMD (Coetzee et al. 2010: 92).

The eighth recommendation was about ongoing assessment and future actions. This is to highlight that the above recommendations are merely an immediate way forward to lessen the already critical impacts. It is stated that these recommendations are there to stabilise the situation, and to understand AMD and the gaps that exist by conducting ongoing research and following up on processes in the priority areas and its potential impacts on the environment. The report concluded that AMD problems will have implications for the future and its impacts will most possibly continue. Management of this process and ongoing assessments will therefore be vitally important (Coetzee et al. 2010: 92).

4.3.3 Role of the Trans-Caledon Tunnel Authority

In April 2011 an entity of the DWA, the TCTA, who manages water projects, was brought in to implement measures to protect water resources (TCTA 2012; DWA 2012: 2) particularly in the Central basin. The TCTA is one of the most important state institutions involved in implementing the IMC policy recommendations. The key objective of the TCTA in this regard was to prevent AMD from entering into the natural environment and in the cases where it is entering the natural environment, to take measures to treat the water to a suitable standard.

The TCTA is one of the bodies that takes responsibility for the short-term solution, namely “the high-density sludge management solution” which has been much disputed among role-players in AMD (TCTA 2012). This is due to the fact that some role-players regard it only as treating the symptoms of AMD and not providing a long-term solution. In addition to this, the treated AMD is not regarded as sufficiently safe for human consumption and agricultural use. As an entity of the DWA, the TCTA has been given this task, because it is the only body that has sustainable bulk infrastructure and the necessary pumping capacity to conduct this task (Nienaber, personal interview, 2013). The water that TCTA is treating through the high-density

sludge management system is pumped into the Vaal Barrage. The problem for the TCTA is that there is not enough money to treat this indefinitely and it is not commercially attractive for the TCTA, because the treated water is not clean enough to sell. The water quality is slightly better than the raw decanted AMD. The TCTA's preferred long-term solution is reverse osmosis so that it can then sell the water to Rand Water or Sasol who will need it. Sasol needs water that is cleaner than drinking water. However, Rand Water publicly stated that it would not buy this treated water, because of the public perception that the water was still acidic and unsafe to drink and, thus, would resist using it (Nienaber, personal interview, 2013).
According to Turton (2013d), these possible risks can be technically managed and "the Rand Water Board investigation into the potential threat of AMD plumes to the hydraulic infrastructure that sustains the economic capital of Africa [i.e. Johannesburg] has yielded the first known high confidence hazard assessment methodology capable of indicating the exact location of risk within". According to him, the assurance can now be given that the risks that stem from AMD in the Witwatersrand goldfields are not in line with that which is projected in the media (Turton 2013d). This is substantial progress for the risk reduction of the problem. The Minister of Water Affairs has appointed the TCTA as the overall project manager, which Turton describes as a "world-class institution" that obtains the necessary skills that are needed to bring the different mining projects in the various mining basins to a successful finish (Turton 2013d).

So far, the policy response to AMD by the national government received attention. The focus shifts now to the provincial government of Gauteng which is mainly responsible for the Witwatersrand.

4.3.4 Gauteng provincial government policy response: Gauteng Department of Agriculture and Rural Development

The Gauteng Department of Agriculture and Rural Development (GDARD) identified MRAs as a possible provincial priority for the reclamation of land in its future five-year programme. The aim of this is to make land available from the MRAs in Gauteng to be used for other government priorities (Hartnady, Turton & Mlisa 2011: 7). The objectives of this included evaluating the current problems caused by mining activities and to suggest how they could be dealt with; quantifying the amount of land under mining activities and classifying them in terms of impacts and prospective reclamation; investigating which mining areas could be made available to be used for other purposes; and providing preliminary and conceptual recommendations on the short-term priorities for the reclamation of the mining sites which could be economically sustainable (Hartnady et al. 2011: 7). MRAs refer to tailings disposal facilities (TDFs), including dams or dumps; waste rock dumps and open cast excavations; water storage facilities and return water dams; tailings spillage sites near TDF dams; and mixtures of building material and mine waste (Hartnady et al. 2011: 7) According to Hartnady et al. (2011:7) there are an estimated 380 MRAs in Gauteng, most of which are made up of the residues of gold mining. The majority of MRAs are radioactive because the Witwatersrand gold-bearing ores contain almost ten times more uranium than gold (Hartnady et al. 2011: 8). The radioactive tailings coexist in these MRAs alongside the iron sulphide mineral pyrite "which reacts in the presence of oxygen and water to form a sulphuric acid solution – the major cause of acid mine drainage (AMD)" (Hartnady et al. 2011: 8). There are three main concerns that relate to MRAs that are located in Gauteng: (1) the air quality, especially dust pollution from MRAs, (2) water-flux and water-quality and (3) geotechnical safety concerns that lead to the dangers of ground instability and collapse above abandoned mine workings as well as unsealed mine shafts that present a threat and danger to the settlements that are nearby (Hartnady et al. 2011: 8).

According to Hartnady et al. (2011: 11), insufficient monitoring and evaluation tend to be the cause for not being able to address the problems caused by MRAs. An approach to deal with this issue will include a multidimensional representation committee – which has also been recommended in the IMC report – in order to follow disaster management principles. This committee will facilitate the development of guiding principles of data sharing and monitoring requirement of MRAs. This also includes those that are responsible for the data and the maintenance thereof, and enforcing policies that are in line with funding and monitoring such as the Mine Rehabilitation Act, which monitors the impact caused by mining activity.

The GDARD Feasibility Study on Mine Residue Areas has identified eight elements, each of which will require separate action. The purpose of this is to identify and reach policy consensus on these eight elements (Harnady et al. 2011: 14). They are discussed below. With regard to the scientific and technical elements of the MRA reclamation issue, elements 1–3 are in line with the human rights outlined in section 24 of the Constitution (RSA 1996).

Element 1 is environmental pollution, including atmosphere- and water-borne contaminant transport, and toxic and radioactive soils. Element 2 is geotechnical stability, which includes possible risks of subsidence collapse of under-mined or dewatered/rewatered ground and the failure of MRA dams. Element 3 is monitoring and evaluation, which include instrumental networks and information systems for monitoring air quality, surface- and groundwater quality.

Elements 4–6 deal with technical and social issues. Element 4 is human health, which involves the epidemiological approach to all aspects of MRA-related or -induced conditions. Element 5 is communication that needs to exist between the various actors in the regulatory environment, polluters and those affected by actions taken by regulators. Element 6 is safety and security, which is a feature of the MRAs.

Elements 7–8 refer to social and socio-economic development goals that would be supported by an effective strategy for MRA reclamation. Element 7 is job creation, which includes the possible options of using local labour for rehabilitation and some long-term land uses or reclaimed land. Element 8 is economic viability, the objective of which is to rehabilitate as much of the impacted land as possible. These elements are discussed in more detail in the report looking at how the problem occurred, the appropriate policy responses and the risks that could arise if action is taken or if it is not taken.

For the purposes of the present study, element 1 and element 4 are discussed in more detail.

Environment pollution (Element 1)

MRAs are known to be the source of radioactive dust, water pollution and soil contamination. Dust is known to be a huge health risk for several reasons and if inhaled it can cause damage to the lung tissue. Thus, dust is a health risk and can reduce the quality of life for many people. Water pollution is associated with abandoned mines and is also closely linked to the AMD problem. MRAs are closely associated with these underground mine voids so there are concerns of water ingress into these voids, which is of great importance. Soil contamination includes the presence of dumps, tailings and slime dams in the surface environment. This takes place where people are contaminated by elevated levels of radiation after unauthorised entrance to a mine site or by living on or near settlements closely situated to a mine on the contaminated MRAs or abandoned mines. Direct access to mine sites can also expose the public to risk due to radon exposure, inhalation and ingestion of radionuclides and chemotoxic metals, and the physical danger that is tied to mining areas (Hartnady et al. 2011: 15).

The policy response to environmental pollution includes several components. Dust should be suppressed. Monitoring and evaluation should take place in a well-structured manner. The management of water ingress is a crucial element of success for any AMD policy in the future and it has also been included in the IMC report on AMD. MRA sites will provide the basis for determining the physical location of each hazardous source. Lastly, the nature of a direct-access pathway of environmental degradation and the requirements of MPRDA Regulation 62 require special attention to affected parties who could be the victims of ongoing pollution and the potential future land users (RSA 2002). If all this is not adhered to, the human health risk will increase over time and this will also put pressure on government (Hartnady et al. 2011:16). With regard to the water pollution, the volume of decanting AMD will become larger and groundwater in the areas adjacent to the different mining basins can become contaminated, which will affect agriculture.

Human health (element 4)

In respect of element 4, human health, several human health risks arise from MRAs and each is driven by root causes. They can negatively impact on the right to a healthy life for all citizens as stipulated in the Constitution which will, in turn, have a legislative impact on local and provincial government. The problem arises where dust from TDFs and sand dumps can lead to respiratory diseases. Close distance between the informal settlements and TDFs can expose humans to toxicity that arises from heavy metal exposure and where there are radioactive elements in the tailings. The increasing levels of AMD can also become a source of future hazard as groundwater can become polluted, which exposes poor and vulnerable communities to further health hazards (Hartnady et al. 2011: 19). The proposed policy response is that all the MRAs be surveyed and mapped with a view of determining the physical location of each source of hazard, be it chemical, radiological and physical. If no action is taken, “the existence of human health risks will also undermine future development aspirations of the Gauteng government by impacting negative on the overall health of residents” (Hartnady et al. 2011: 19). However, to reduce human health risks, informal settlements will need to be rearranged. However, the residents of these informal settlements could resist removal.

4.4 Developing Long-Term Solutions to Acid Mine Drainage

Aurecon is a private company that provides engineering, management and specialist technical services to public and private sector clients globally (Aurecon 2013). The DWA put out a tender advertising an 18-month feasibility study for a long-term solution to deal with AMD in the three underground mining basins. Aurecon was the successful bidder (DWA 2012: 2). In an interview with Shanna Nienaber (2013), she stated that DST sat in on DWA meetings with Aurecon. The situation in March 2013 was that Aurecon was providing advisory services for the DST to assess and evaluate alternative approaches to water treatment and water management as a means to improve the quality of water produced by the TCTA treatment process of AMD.

An inception report compiled by the DWA discusses the short-term interventions to addressing AMD. These interventions include (1) investigating and implementing measures to pump the underground mine water to prevent it from crossing the ECL; (2) implementing measures to remove metals from AMD and (3) developing a feasibility study (DWA 2012: 3). This inception report looks at all the same interventions with regard to long- and short-term interventions to maintain or neutralise the water so that it does not reach the ECLs. A key element mentioned in this report as part of the long-term solutions to address AMD that is relevant for the present study is “the possibilities for the use or discharge of raw, neutralised or desalinated AMD which will meet the objective of reducing the salt load on the Vaal River System to acceptable levels and which do not have an unacceptable social and environmental impact” (DWA 2012: 7).

4.5 Consultants, Activists and Non-Governmental Organisations

The AMD debate has been ongoing for over a decade now, which has led to numerous public fights and attempts to place blame on some and “seek redress from well-meaning activists” (Turton 2013d).

According to Turton (2009), civil society is emerging as a key policy entrepreneur that derives its energy from public opinion after years of exploitation from the government and the mining industry that stemmed from their ambition to hold those responsible for abusing human rights. He adds that a range of NGOs have been taking on the issue of AMD, including the FSE under the lead of Mariette Liefferink.

Liefferink continuously stresses the urgency and impact of radioactivity that has been caused by AMD. According to Fig (2011: 312), the national nuclear regulator has not succeeded in protecting the public from the radioactivity associated with AMD. In 2010 the impacts of uranium and other radioactive substances in the Wonderfonteinspruit catchment did not note any danger to communities however, this was challenged by radiation exerts. Liefferink (personal interview, 2013) stated that radioactivity would harm communities and the people who lived in areas surrounding mines.

The community of AMD specialists in South Africa is very diverse and does not only include government officials and policy-makers or the scientists at the main science councils, but also mining and business specialists, consultants who are used by either government or the private sector, and activists in the NGO sector. All of them have their own interpretation of what AMD entails, how serious a threat it poses and what the steps should be to avoid a crisis or to find a long-term and sustainable approach to it.

For the purpose of identifying policy responses originating from outside the government sector, two prominent people – Anthony Turton and Mariette Liefferink – can serve as case studies.

4.5.1 Anthony Turton

Anthony Turton (personal interview, 2013) describes himself as both a consultant and an activist. As a consultant (TouchStone Resources) he regards himself, in the first instance, as a political scientist and not a mining scientist; he obtained a doctoral degree in the politics of water management in southern Africa (Turton 1988). Some of his best-known work as a consultant is done for companies such as Mintails and major banks (Turton 2013c). During his previous employment at the CSIR he was instrumental in raising public awareness about AMD and its possible impacts (Turton 2013c).

Turton's approach is to publish extensively and to act as a public speaker. At the same time, he is often part of a technical team that concentrates on the use of technology and engineering science in searching for solutions that can also introduce new business opportunities for mining companies. His view, in general, is that the IMC's approach (which is implemented by the TCTA in the Central basin) of pumping underground water to below the ECL, is not a long-term solution but mainly deals with the symptoms of AMD. Derived from his description or definition of AMD (discussed in Chapter 3), which is not limited to acidic underground water but also includes surface water from the tailings dams that interact with acid rain in the MRAs, Turton's approach to AMD focuses very much on the MRAs.

The business model of Mintails in which Turton is involved consists of reprocessing the gold mines' tailings dams, extracting the remaining gold from the sludge and relocating the residue to a "super dump" (Turton, personal interview, 2013). In addition to producing gold, this process also reduces the formation of surface-generated acidic and radioactive water; it will reduce the prevalence of mine dust near residential areas which is responsible for serious respiratory illnesses; it will create new space at the previous MRAs for residential developments and other spatial developments; and it will centralise management of the MRAs at the "super dump" (Turton, personal interview, 2013). Turton (personal interview, 2013) stated that Mintails had compiled principles to guide its approach to the future solutions for the AMD problem where responsible. This included finding an inclusive approach to the management of MRAs and the surface TDF was essential to solve the AMD problem. The removal of existing TDFs and other contaminated dumps should be encouraged, where land can be rehabilitated and used for social and economic purposes. The consolidation of TDFs should be encouraged as part of an inclusive MRA management process to increase the life of mining from 2020, which will create employment opportunities and ample time for effective rehabilitation of all mine-impacted landscapes (Turton, personal interview, 2013).

Complementary to the business approach, Turton maintains that his activist role is still necessary for enhancing public awareness about AMD. He uses social media such as Facebook but warns against sensationalism, especially about the radioactive dimension of AMD and inappropriate use of litigation against mining companies which sometimes have counterproductive outcomes (Turton 2013b). He acknowledges that since the first known decant in the Western basin in 2002, the AMD issue has been characterised by an inadequate response by all the stakeholders involved. The Trustees of the Water Stewardship Council of Southern Africa (WSCSA) hold the view that there needs to be a change from "blame-seeking to solution-seeking behaviour". Turton (2013d) is also of the opinion that negative media coverage will only wrongly alert the public and that the public has not been adequately informed. Turton as a case study, therefore, combines scientific, business and public awareness approaches in his search for more cost-effective and sustainable solutions than those adopted by the government since 2011.

(Source for photograph: Researcher's collection

Figure 4.1: Anthony Turton and the researcher

4.5.2 Mariette Liefferink

Mariette Liefferink, as the second case study, approaches AMD mainly from the perspective of an NGO or community-based organisation and concentrates on the social impact of AMD. She serves on government-appointed committees, informs ministers and works with many key players to ensure that there is some way forward to resolving the problem (Fig 2011: 315). Her main objective is to create public awareness and to identify "hot spots" that are responsible for detrimental social and environmental effects. Liefferink's activism on AMD and raising of the public's awareness has been noticed by a significant number of people in the field. Fig (2011: 315) describes Liefferink as "working tirelessly for a number of years . . . not only has she been a public advocate of the need for solutions, but has personally kept the media and affected communities informed, mobilising resources to draw attention to the problem in new and creative ways".

Liefferink not only serves on government and parastatal bodies (e.g. the nuclear energy regulator) but also as a civil society representative. She uses the media extensively to influence public opinion and to highlight the consequences of government actions or lack thereof. In one particular instance she warned about the acidic and radioactivity threat of mine water that could affect central Johannesburg when it reached the anticipated critical point in 2013 (*Noseweek* 2013: 10). She explained how pumping was to take place in an attempt to prevent radioactive AMD from flooding the streets of Johannesburg where “deadly liquid” was predicted to reach the ECL (*Noseweek* 2013: 10). She stressed the issue that if AMD was not prevented, Gold Reef City stood the chance of being flooded and AMD would “eat away Joburg’s subterranean infrastructure, contaminate its dolomitic aquifers and start percolating upwards to seep out the ground in the CBD and Boksburg” (*Noseweek* 2013: 10). She also warned that the rising water was likely to increase the seismic activity on the Witwatersrand and cause more sinkholes in dolomite areas. She stated that mining companies, political authorities and the nuclear regulator had been aware of these issues since 2002, but no emergency plans were in place and the radioactive water was flowing into the wetlands or was being pumped into nearby lakes and dams.

In her public awareness campaign Liefferink focuses extensively on the radioactive water in the Johannesburg area and the surrounding towns. Her approach is to activate public support against the consequences of AMD and radioactive mine water. Part of her approach is to confront key stakeholders directly and, as a result, she has been appointed to serve on several committees and boards. She also takes parliamentary members on tours and has conducted many workshops with thousands of people informing them of the seriousness of the issue (*Noseweek* 2013: 14).

Her organisation, FSE is often involved in litigation with mining companies or addressing instances where abandoned mines or residue areas pose a direct environmental or health threat to communities (Funke, Nienaber & Gioia 2012: 193). Litigation becomes then an instrument of pressure against those who violate the official water management regime. At the same time, those cases also enhance public awareness about the AMD complications. Funke et al. (2012: 193) described Liefferink as a “news carrier” of AMD; that she educates the people by making them aware of the issues at hand and she chases after the government to address these issues. Liefferink’s activism “goes beyond protecting the environment for the environment’s sake and focuses on the effects environmental damage has on the public’s health and well-being” (Funke et al. 2012: 200). This was also evident during the researcher’s tour with Liefferink on the West Rand. On the one hand, she discussed the impact of AMD but, at the same time, provided assistance in the form of food to the children in Kagiso informal settlement.

Liefferink does not necessarily publicly propose alternative models or business approaches to the government's strategy. Her cause is more to call for sustainable and vigorous implementation of existing government policies. She, however, differs from government on the radioactive issue: she considers it a much more omnipresent factor than most of the officials do. She also differs from Turton on the business approach and Mintails' approach. In a qualified sense she is critical of the fact that "many persons and companies want to financially profit from the current situation" (Liefferink 2013). On behalf of FSE, she insists that "scientifically sound" environmental impact assessments and public participation of short- and medium-term treatment of AMD, and public involvement for the long-term treatment must be brought back. In this regard, she endorses North-West University's Prof Frank Winde's criticism of Mintails' Tailing Water Treatment technology, because its environmental impact is still unknown (Liefferink 2013).

(Source: author's collection)

Figure 4.2: Mariette Liefferink and the researcher

The two cases illustrate the different approaches of Turton and Liefferink in proposing solutions for AMD. Both share an activist approach that emphasises the importance of influencing public opinion in policy-making and governance, and the public watch-dog role civil society can play. They also differ in their approaches: Turton acts more as a business consultant, while Liefferink serves on government bodies. She uses litigation as an enforcement instrument, while Turton does not. Liefferink regards the radioactive threat of AMD at a much higher level than Turton. Both of them have played exceptionally important roles to elevate AMD to the level of a public issue. What is significant is the fact that both have become indirectly very important role-players in the evolution of the policy on AMD.

4.6 Conclusion

In this chapter the focus was on the different responses to AMD. The first was the question of governance and on how water management is conducted in South Africa and how appropriate it is to address AMD. It raised the contentious issue of who is responsible for funding the rehabilitation of closed or abandoned mines which is a major contributor towards AMD. In the discussion it has become clear that AMD is a "legacy" problem caused partly by the fact that an unnaturally close relationship between the mining sector and the government in the past effectively exempted the mining houses from preparing for mine closure and the resultant effects. Part of the response to AMD in the past number of years is therefore also to pay renewed attention to a sustainable policy on mine closures.

The government's main instrument in response to AMD is the IMC, the options it identified and the recommendations it made. Most of them were accepted as the government's formal policy framework on AMD. The policy consists mainly of pumping the mine water from existing shafts and keeping the water level below the ECL. The pumped water is then treated but the sludge residue still has to be managed. Most of the evidence presented in this study reached the consensus that the treated water is not yet ideal for human consumption and, therefore, better long-term solutions are still being investigated. In this chapter it is concluded that the IMC expert report concentrated on the technical-scientific aspects of AMD but did not attend at all to its socio-economic impacts. This shortcoming in the government's policy response is accentuated in the approach followed by activists such as Anthony Turton and Mariette Liefferink. This chapter demonstrated that they also differ in their approaches. They are, however, both critical of the current approach, because it is regarded as a short-term solution dealing only with the symptoms of AMD and does not provide a long-term solution that will be sustainable in a socio-economic sense.

The absence of a socio-economic focus in the policy response is therefore the motivation for the next chapter.

CHAPTER 5: SOCIO-ECONOMIC IMPACT OF ACID MINE DRAINAGE

5.1 Introduction

In the previous chapters the nature and scope of AMD were discussed. The different responses to AMD were also identified. In view of the fact that the objective of this study is to investigate whether the government's policy response is appropriate for the dynamics of AMD, it is important to determine what its socio-economic impacts are or could be. The impacts of AMD can then be linked to the policy response. This chapter, therefore, discusses the socio-economic impacts of AMD. It incorporates the environmental, social, economic and health impacts that contaminated mine water has or could have on communities who live in areas surrounding a mine.

Even though the mining sector is such a big consumer of water – as mining needs water to conduct their activities – agriculture is the biggest water consumer in most countries in the world and consumes almost 70 per cent of the world's freshwater (Parris 2010). In this chapter, agriculture is chosen as a specific focus area, because it is the sector potentially most affected by water problems and it also combines different socio-economic aspects. On the one hand, agriculture depends on a sustainable environment in the form of quality soil, water and atmosphere. On the other hand, agriculture delivers products essential for human life. Contaminated water can have a severe impact on both aspects of agriculture and on society as a whole.

During the fieldwork stage of this study an interview was conducted with representatives of AgriSA. AgriSA is part of organised agriculture and an organisation that promotes the development, profitability, stability and sustainability of commercial agriculture in South Africa through its involvement in, and input at, the national and international policy level (AgriSA 2013). The interviewees provided crucial insight into how AMD is impacting on agriculture. This will be discussed later.

This chapter refers to case studies of farmers' experiences of contaminated water that negatively impacted on their farming activities. Lastly, the chapter suggests possible solutions to reduce these negative impacts.

5.2 The Economic, Environmental, Social and Health Impacts of Acid Mine Drainage

There are several negative impacts associated with AMD-related pollution loads, including financial risks, environmental, socio-economic, health and political. These impacts are discussed in an integrated manner in this section due to the nature in which they relate to one another. From media reports it has become evident that there are clear socio-economic issues regarding AMD and those who will be potentially affected by it. Shanna Nienaber (personal interview, 2013) believes that the strategic issue is the water supply in the Vaal Dam. The whole of Gauteng is a massive water hub and water security has become a major problem. AMD is a long-term problem that needs to be dealt with. It is a threat to people who live closest to areas of water spillage, to those who depend on boreholes and those growing vegetables in the affected areas. This becomes part of a strong case to make because it impacts on people who live in mining areas in general and it is difficult to separate AMD from the issues of tailings dumps from the issue of dust that blows off these dumps to the soil quality that is affected. In this regard, Nienaber (personal interview, 2013) states that this is not just an AMD problem but an integrated problem.

AMD is complex, not all these areas are affected in the same way and neither do all of them have the same levels of pollutants (Nienaber, personal interview, 2013). Nienaber (personal interview, 2013) states that communities are affected, especially those who are near tailings dumps, and it is not just the groundwater that is polluted but also the run-off from the tailings dams themselves. There is a big debate between scientists and communities about the impact of rain on the surface which causes seepage of mine water and water from tailings dams.

The WRC is deeply involved in AMD and long-term water quality management. From 2005, the WRC has increased its focus to include AMD with the emphasis on tools for long-term water quality management in underground collieries, including the quantification of the potential and magnitude of AMD under South African open-cast conditions (Frost and Sullivan 2011: 4). The research conducted included the impact of mine water-related research in South Africa. These impacts are discussed in line with its current and potential benefits (Frost & Sullivan 2011).

In Chapter 4 it was already observed that the IMC policy document had overlooked the socio-economic impacts caused by AMD and they were not placed at the forefront of the agenda. The IMC report mentions as a ‘concluding point’ that risks of mine water decant include serious negative ecological impacts on the receiving environments, and local and regional impacts on the Vaal and Crocodile River systems that could affect fitness for use of the receiving water resources to downstream water users. “AMD will aggravate an already upward trend associated with salinisation of the receiving river systems, necessitating additional dilution releases to be made and subsequently risking water supply security within the integrated Vaal River System” (Coetzee et al. 2010: 87).

More public awareness of mine water spilling out into the environment and, at the same time, strong sentiments that exist between the mining industry and the government have made AMD a highly politicised issue. Mine closures and the related increase in AMD have also had serious economic consequences for communities who were previously supported by the mining sector. Mine closure has, in certain instances, led to the loss of job opportunities and, therefore, increasing unemployment rates. “Subsistence farming is often the last resort for such communities, but AMD may render the available water resources unfit for agricultural use” (Oelofse et al. 2007: 6).

The economic implications of AMD when it causes local flooding are that it can increase the risk of ground deformation and attack structures made by human beings such as concrete building foundations, the liners of landfills and waste dumps. In some parts of the United Kingdom this is known as one of the main causes of freshwater pollution. Cobbing (2008: 452) states that “AMD problems generally improve naturally with time, with pH rising and dissolved load falling, but this can take decades or longer”. What becomes questionable here is that given these facts, one needs to see the measures that the identified institutions are taking to reduce the risk of it reaching a crisis stage. Even though it is possible for AMD problems to improve “naturally” with time, as mentioned above, this can be beneficial for the environment, but what then happens to the human element in the meantime.

Tourism is an important economic sector in South Africa. The potential impact of AMD on tourist facilities should be considered. According to Peter Mills (personal interview, 2013), some people believe that the Cradle of Humankind World Heritage Site will be destroyed by the acidic effect of AMD on the underground fossils but he feels this can be disputed. When asked about the effects of alarmist media reports on the possible impacts, he responded that “tourism is growing; the only impact that there has been is a rise in the water table at the Cradle and the high rainfall season caused this. Before the rainy season the water table remained at the same level as before decant started in 2002” (Mills, personal interview, 2013). He added that no one knew what the exact impacts of AMD were. In his mind, the impacts on the Cradle were not negative and were rather limited. He believed that there had not been many negative impacts on tourism but it had harmed farmers. Hypothetically, according to him, if hotels were to be established around the area, then there would be a need for an alternative source of better-quality water. He stated that “there are more pressing issues than AMD, all the fossil sites are above the water levels and speculation about the Cradle being under threat is not true at this point” (Mills, personal interview, 2013).

Anthony Turton (personal interview, 2013) also looked at the economic impacts cause by AMD and how they could be changed. The most significant is the coexistence of poverty spatially located in close proximity to MRAs (as discussed in Chapter 4). About 1.6 million people now live in informal settlements that are situated close to MRAs. Turton explained why MRA land was used more by informal settlements. In the 1900s the population of what is now Gauteng consisted of 0,7 million people, which increased to 6,2 million in 1994 and will grow to 20 million in 2020. Thus, in terms of households, one will see a growth from 1,8 million units in 1994 to 4,7 million in 2020 (Turton, personal interview, 2013). It is evident that there is not enough land to keep up with the increase in formal settlements. Turton’s (personal interview, 2013) proposed solution is to remove the TDFs, by consolidating them into “super-dumps engineered to twenty-first-century standards, with a potential yield of 5445 hectares of land that could be brought into the revenue stream of local authorities through rates and taxes".

By removing the TDFs, future acid generation will be prevented and make significant areas of land available for new developments. Where there are informal settlements on MRA land, residents could be contaminated by heavy metals such as uranium, and some people have lost their lives after falling through unprotected openings into the mine void. Houses in those areas run the risk of being redlined by financial institutions, making it impossible to sell them, or of being excluded as collateral surety for the raising of capital from a bank. This will have clear implications for poverty eradication.

According to Turton (personal interview, 2013), the second significant socio-economic impact of AMD and its economic implications relates to the eradication of the apartheid-era heritage which is still evident in the form of segregated communities. Large MRA land is often a physical barrier between the historically black township areas and the historically white suburbs; for example, Kagiso, a township in Krugersdorp, is spatially separated from the rest of Krugersdorp due to the existence of an extensive MRA that is owned by Mintails (a company whose main gold-mining activities are on the Western basin of Witwatersrand Goldfields). Enormous illegal mining activity is currently taking place in this area and there have been cases where miners have lost their life. The way in which rehabilitation of MRAs can end this divide is to create land that would link these historic divides in the way Mogale City (the local municipality in the West Rand area in Gauteng) wants to do with part of the Western basin MRAs.

(Source: Researcher).
Figure 5.1: Kagiso Township on the West Rand

(Source: Researcher).
Figure 5.2: Impact of AMD on the soil in the Kagiso Township on the West Rand

The third socio-economic impact of abandoned mines is that illegal mining activities (known as '*zama zama'*) take place, which leads to the criminalisation of communities (Turton, personal interview, 2013). This has several harmful consequences such as risks to individual informal miners who have no financial or other benefit structures and who are constantly exposed to death or injury. There is the risk of the loss of the breadwinner in an impoverished family should an accident occur, which can be caused by several factors, including illegal mining activities; the creation of criminal networks needed to process illegal gold, stolen copper and jewellery; the creation of new ingress points into the void as shallow stopping continues; the erosion of structural integrity of roads; and the creation of dangerous openings into the earth that can later become a hazard to the children who play in the area. Lastly, illegal mining often means the opening of closed shafts in order to gain access to shaft pillars which are rich in ore grade but which are still needed in provide support for the structural integrity of old underground workings (Turton, personal interview, 2013).

The economic impact of the developments in the Eastern basin, especially at the Grootvlei mine after the holding mining company had been liquidated and taken over by Aurora Empowerment Systems, was far-reaching. It included the majority of the workers in the Grootvlei mine who would not have received payment should the mine have flooded and being forced to move to hostels in the area due to desperation. The electricity and water supply to the hostel was cut off, the catering services had stopped, the toilets were not usable, and the medical attention ceased. This created problems for the workers and led to strikes where the workers had to eventually accept hand-outs to ensure their survival. Their diets had changed, as some were eating thin maize porridge. The workers who were diabetic did not obtain an adequate diet and complained of their medication not being effective. Sanitation was a problem and the facilities did not comply with the minimum acceptable standards. In addition, there was insufficient water for bathing. Some of the workers could not afford to keep their children in school due to lack of income and their inability to pay school fees and transport. For other workers, the lack of income led to family structures being broken because they could not support their wives and children (Fig 2011: 309).

Another area of socio-economic impacts is the environmental dimension. The environmental risks associated with AMD include surface and groundwater pollution in the form of heavy metal uptake in the environment, the degradation of soil quality and the harming of aquatic fauna.

AMD has several environmental impacts that will be extremely costly to undo. AMD associated with gold mining activities frequently include radionuclides as most of the heavy metals and radionuclides are not only linked to surface water pollution, but are also responsible for degrading soil quality, aquatic habitats and for allowing heavy metals to seep into the environment (Frost & Sullivan 2011: 23). As mentioned in Chapter 3, acidic water started to decant from the underground workings of defunct flooded mines on the West Rand in 2002 already and AMD effected the natural water course that flows through the Krugersdorp Game Reserve towards the Cradle of Humankind World Heritage Site. It caused damages to the ecosystem and the wildlife in the game reserve (Frost & Sullivan 2011: 24). The WRC's research into mine water management aims to reduce the negative environmental impacts that have been caused by mining activity in the area. The research aims to reduce the degradation of soil quality, which will increase land for farming and will, therefore, increase agricultural production It will prevent surface water pollution, which will lessen the deformities at birth and defects in animals; there will be more aquatic life and livestock; and, lastly, it will limit the groundwater pollution which will improve the quality of drinking water (Frost & Sullivan 2011: 24).

Arguably the most serious concern about AMD is its possible health impacts on human beings. The contaminated groundwater might unknowingly be consumed by individuals, with medical treatment often ineffective by the time the symptoms materialise (Hobbs et al. 2008: 421). Health-related issues that are known to have surfaced are, for example, "in Delmas, near Johannesburg, where typhoid fever related to poor groundwater quality has killed people on two separate occasions" (Cobbing 2008: 452). Such problems could start affecting the other areas if not addressed.

The socio-economic impacts are more often referred to in media reports, and mentioned by activists and NGOs trying to mitigate the effects of the AMD. Taylor (2013: 10) discusses how the polluted water systems can affect the health of communities. While a focus in this study is on the impact of AMD on public health, very often water quality is affected by a combination of factors and the singular impact of AMD cannot always be isolated effectively. According to Dr Jo Barnes (in Taylor 2013: 10), who is an expert in epidemiology and community health, the health crisis due to high levels of pollution and sewerage in the water goes as far back as 1998 and the necessary action is often not taken. An example is that of the Eerste River in Stellenbosch, where “in the dry season when natural water levels are low, parts of the river can be 80 percent sewerage effluent”. In the past, people who lived alongside the river had to evacuate their houses because of the lack of water safety of the river (Taylor 2013: 10). With sewage already polluting the water, the additional impact of AMD on the river systems near these communities will only be more detrimental. Some farmers even struggle to export their crops, because they are grown using contaminated water. However, during an interview with the representatives of AgriSA they concluded that there was no empirical evidence to demonstrate that AMD had an immediate effect on farming in the area of the present study. However, the case in Stellenbosch provides insight into the possible socio-economic impacts of polluted water, while case studies discussed later can direct one towards the possible impacts caused by AMD in the three river basins (Opperman, du Plessis & Louw, personal interview, 2013).

According to Mariette Liefferink (2013), all wetlands in the Witwatersrand contain heavy metal contaminants. Leukaemia is one of the health impacts known to arise from this. She uses the example of Robinson Lake on the West Rand and explains how there is no aquatic life left, and how soil and vegetation are negatively affected by AMD. Immense effects on health are known to arise from the inhalation of uranium particles:

> Highly insoluble uranium compounds may remain in the alveoli [air sac] whereas soluble uranium compounds may dissolve and pass across the alveolar membranes into the bloodstream, where they may exert systemic toxic effects. There is also known to be insoluble particles that are absorbed into the body from the alveoli. Insoluble particles may reside in the lungs for years, causing chronic radiotoxicity to be expressed in the alveoli. (Liefferink 2013)

The health impacts are also reiterated by Taylor (2013: 10), who states that polluted water can carry respiratory illnesses and heart viruses. Liefferink (2013) noted that the water that Rand Water sold was of good quality, but it had not been tested for heavy metals. Liefferink added that up until 2003 the World Health Organisation and the South African Bureau of Standards regarded water with a high uranium concentration (i.e. 2 µg/ℓ) as unsafe to drink. However, the DWA regards 80 µg/ℓ as safe, while the global freshwater average is 0,4 µg/ℓ (*Noseweek* 2013: 11). Liefferink states that there are thousands of vulnerable, malnourished, immunity-comprised people who live in shacks among the abandoned mines in the Far West Rand and they are exposed to radioactive poisoning; “uranium contaminates the food they grow, the fish they catch and the air they breathe” (Noseweek 2013: 11). The National Nuclear Regulator (NNR) stipulates that half of the sites measured in the Wonderfonteinspruit area exceed the safe limit for external radiation (Noseweek 2013: 11). Liefferink (*Noseweek* 2013: 11) states that the damage that this is doing to the people is not known exactly and she adds that “for all the counting of uranium levels in the water, soil, plants and animals over the past two decades, no-one has bothered to do any epidemiological studies on the people”. She adds (Noseweek 2013: 11) that even if a small amount of uranium is ingested, it chemically attacks the kidneys and the brain, can disrupt the endocrine system, and can affect the immune system. The poorer people who live along the mine dumps will experience this and may be ill for years to come.

The health impacts resulting from contaminated water on human beings tends to be increasing as more and more activists and media reports are providing information on actual incidences that have occurred. These illnesses that arise include cancer, which results from ingestion and exposure to unsafe levels of radionuclides (Frost & Sullivan 2011: 34). Mine water pollution in the Western basin and communities that live in those areas are the most exposed to the risk that comes with decanted mine water drainage. Mine water causes illnesses that lead to death or absenteeism from work, and this leads to loss of income for a family, especially through the death of the income-earner (Frost & Sullivan 2011: 34-35).

The health risk caused by tailings dams can be reduced by the improved management of dust. A significant component of tailings dams consists of uranium and other heavy metals, and dust that arises from mines dumps also carries a significant load of health-related risks. Dust management objectives can only be achieved once the tailings have been placed in a final resting place and fully rehabilitated to include revegetation (Turton, personal interview, 2013).

Representatives and officials of government are hesitant to concede that AMD can have these consequences or impacts. Acknowledging the socio-economic impacts will depend on how cost-effectively they can be addressed. Peter Kelly (personal interview, 2013) stated that if the technical solutions to AMD were adequate then the social impacts would be minimal, and thus, “government cannot afford for the technical solution to not be successful”.

5.3 Negative Socio-Economic Impacts of Acid Mine Drainage: Agriculture as a Case Study

5.3.1 The Krugersdorp Game Reserve

There are several useful case studies that depict the impacts that AMD has had on agricultural activities. The first case study is not about agriculture on its own but about the impact on animals in general. The Krugersdorp Game Reserve has experienced mass water pollution since 2002 as a result of uncontrolled discharge of contaminated water from abandoned mines within those catchment areas. This has led to a drastic increase in the animal mortality in the reserve. It was reported that little has been done to try and find workable solutions, and complications with the animals’ health had developed shortly after they had been in contact with polluted water. Two mining companies had placed water treatment plants near Krugersdorp and irrespective of their neutralising of the acidity, the metal concentration in the treated water was still higher than normal where it flows into the Tweelopiespruit just before the Krugersdorp Game Reserve. Even though the water is treated, it is “murky brown and turns plant life orange, a result of high iron and manganese levels” (Frost & Sullivan 2011: 30). Pollution coming from the mines has caused groundwater contamination in the Tweelopiespruit. There has been a decline in aquatic life and numerous animal mortalities, which are all connected to the Tweelopiespruit pollution caused by mining and attributed to the quality of water

(Frost & Sullivan 2011: 30). The company African Bush Adventures, who manages the reserve, wrote to the DWA about the death of aquatic life and buffalo, and rhino babies that had to be aborted (Frost & Sullivan 2011: 30).

5.3.2 Lotter farm Krugersdorp

The second useful case study of the impact of AMD is that of farmer Dawie Lotter who conducted his farming activities outside Krugersdorp next to a mine water treatment plant. The plant was set up to deal with AMD, but his land could not be farmed and became unusable due to decanted water flooding it. This resulted in deposits of toxic metals and acid that seeped into the sand and turned orange. It even stopped the grass from growing. According to Lotter (in Frost & Sullivan 2011: 33), farming used to be very profitable until his land became contaminated with AMD due to mining activity within the area. He added that he had imported horses which he reared and trained on his land, but within two years, eight of the horses had died and the rest were ill, which forced him to sell them. Lotter's brother also tried to make a living from rearing cattle and sheep off the land but he also experienced losses within a few months and had to sell the rest of the flock. Thus, this land was rendered unusable and the Lotters reached an agreement with the mining company to buy out the farm (Frost & Sullivan 2011: 33).

5.3.3 Farming activities in the Fochville district

The third case study is the water pollution in the Fochville district. Since 1998, the farmers in the Fochville area had noticed that the quantity and quality of their crops, produce and livestock production were declining. They speculated that it was caused by the salt load and heavy metals from mine effluent flowing into the Leeuwspruit Catchment. A farmer residing in that area, Pieter Rheeder, had been forced to stop his farming activities due to the poor groundwater quality, which impacted negatively on the plants. The only available water, which was the borehole water, was also deteriorating, and became unfit for human and animal use (Frost & Sullivan 2011: 34).

5.3.4 Wonderfontein Catchment area

The fourth case study is that of the Wonderfontein Catchment area. This area is situated between Johannesburg and Potchefstroom and includes the richest gold mines in the world (Frost & Sullivan 2011: 36). Gold ore from these mines also contains uranium and approximately six billion tons of tailings contain about 600 000 tons of uranium which is exposed to the biosphere (Frost & Sullivan 2011: 36). The services of the Cancer Association of South Africa (CANSA) are available to residents in Randfontein and Carletonville to monitor their health conditions. Residential areas that are in close proximity to the mining operations as well as CANSA have been confronted by the local NGOs to identify what the possible risk of cancer is in this environment. In 2008, three CANSA employees went on a visit to a tailings area in Carletonville and were exposed to dust, because they were seated in an open vehicle. They experienced symptoms of headaches, loss of appetite, eye irritation, sore throats, nausea, severe diarrhoea and skin rashes (Frost & Sullivan 2011: 36). The chemical and physical properties of the tailings dust in the area were analysed to determine why the employees had become ill. The outcome was that the CANSA employees' illness was due to being exposed to, and possible inhalation of specific deposits of tailings dust that was both radioactive and arsenic (Frost & Sullivan 2011: 36). This is directly related to Turton's and Liefferink's definition of AMD in Chapter 3.

The agricultural sector is involved in experimentation to determine how the negative impacts of AMD and contaminated water can be overcome. According to Opperman et al. (personal interview, 2013),

> In the Wonderfonteinspruit one always hears of farmers complaining about radionuclide contamination of the crops that are produced; there is also the salinity aspect. A lot of experimental work is being done with the use of the water in the gold fields (treated water) and this has been successful, there is a possibility that agriculture can make a contribution to solving some of the problems associated with contaminated water from which they can benefit. The Grootvlei, for instance, has neutralised the water. In the Blesbokspruit farmers were successfully irrigating with that water.

Thus, AMD and the issues that surround it are known to have numerous socio-economic consequences, but addressing these issues step by step can lead to finding a means to an end.

5.4 Possible Solutions to the Socio-Economic Impacts (Mainly in Agriculture)

Water is essential for the social, economic and environmental good of humans, animals and plant life, and it is essential that water-related policies are implemented in ways that pay attention to the poor so that they too can meet their basic needs (DWAF 2008b: 12). “Government policy since 1994 has focused strongly on equitable and sustainable social and economic development for the benefit of all South Africa’s people” (DWAF 2008b: 10). All national legislation mentions that socio-economic aspects need to be taken into account, to achieve efficient and effective water use. In 2008 the Department of Water Affairs and Forestry updated the National Water Resource Strategy (NWRS). The driving principle for this change was the vision for a “robust and accountable water sector, which successfully meets demands for water security and reliable and effective water services, and enables equitable, environmentally sustainable economic growth and social development in South Africa” (DWAF 2008b: 10). A few important principles stemmed from this process, which is significant for the present study. The decisions regarding the use of water must balance the economic, social and environmental dimensions of water. Sustainable service provision and water management rest on a strong partnership between citizens and government with mutual accountability (DWAF 2008b: 10). However, with the fast pace required to address AMD and to prevent further harm to the environment, the socio-economic impacts do not seem to be accounted for or are not prioritised, and neither is there much discussion nor are workable solutions presented for how they will be addressed.

Peter Kelly (personal interview, 2013) views AMD as more of a technical issue than an environmental one and believes that only if the technical issues are not addressed adequately can they become an environmental issue. A technical issue means that it would ultimately need a technical solution. The problem with such an approach is that the socio-economic impacts are overlooked. When the environment receives priority, then human health is not entirely considered or placed as a concern. Kelly (personal interview, 2013), however, hoped that AMD could be managed in the future, that the implications would not be far too horrific to consider and that the social implications would not be too extensive.

In addition to the fact that the South African government has policies in place to protect the country's water resources, there are also policies in place that protect the rights of the public. The government departments who are in charge of ensuring that the water resources are used in a sustainable manner and that can sanction transgressions, however, are not empowered also to enforce remedies to the socio-economic impacts. Thus, there needs to be a 'working together approach' by all the role-players to ensure that everyone played their part in solving this issue. Those responsible must clean up the damage; the government as the custodian of the water resources has to play its role in addressing AMD by ensuring all available advice on the environmental and socio-economic impacts and on the health of people become available to addressing AMD from an approach that favours all, that is, protecting the water, the environment and the citizens who live in the affected areas.

When planning for the closure of a mine, the anticipated social impacts should also be included. Communities will be affected by mine closures and if they are directly affected, then water management strategies, health and safety issues, and possible employment opportunities should be considered as proposed strategies to counter the negative impacts. Closure should, however, be planned in such a way that it will not have a negative impact on other water users (DWAF 2008a).

Gauteng is a growing province, and is also growing in economic and industrial needs. For these reasons more water is needed in this area. Therefore, the second phase of the Lesotho Highlands Water Project is under way. The TCTA currently pumps water into the Katse Dam to Clarens as part of the Lesotho Highlands Water Project scheme. The water is then channelled by river to the Vaal Dam for service in Gauteng. This is costly, because it requires sophisticated infrastructure and that the Lesotho-Highlands is also the second source of water (Nienaber, personal interview, 2013).

Alleviating the economic impacts includes revenue generation, mine water irrigation and crop production. Crop irrigation using treated mine water can be profitable, environmentally friendly and economically sustainable. Thus, using neutralised and desalinated mine water can have the potential benefits of increased agricultural productivity at regional and country level due to commercial crop production on a large scale using mine water for irrigation. By treating the water using water treatment plants, society can gain significant benefits such as the provision of clean piped water and suppression of dust for communities living in and near the mining areas. The use of research by industry in metal removal processes, water treatment processes and environmental rehabilitation processes produce useful industrial materials. By-products such as gypsum derived from water treatment processes can be used to manufacture building materials, fertilisers and mining products. Ferrite can also be used in other mining operations if metals are removed. The points mentioned above can all lead to job creation (Frost and Sullivan 2011: 9–10).

During an interview with AgriSA, the interviewees were asked if treated mine water could become an alternative source of water which was not accessible in the past or if it was by coincidence that it became part of the available water resources. The response was that if referring to the total water balance this water was always there but it was pumped out over a period. When this pumping took place it was pumped out of the water system completely, but “we do not have good-quality water resources available like there was in the Witwatersrand before the Goldfields” (Opperman et al. personal interview, 2013). Will the treated mine water create new opportunities for agriculture? AgriSA was of the opinion that agriculture was already experiencing a water deficit and the demand was still growing but that it would stabilise if water could be released from the dams. At the same time, the released water could be used to dilute the treated mine water pumped into the rivers and the other forms of river pollution. The danger, however, was that if water released to dilute the water to an acceptable quality was not well managed, less water for household use would be available and the quality of the water for domestic users might also be lowered (Opperman et al. personal interview, 2013).

The use of treated mine water for agricultural irrigation can create jobs, as an additional labour force would be needed to meet the demands that come with the increased production. The use of mine water for irrigation has implications for South Africa in general and the agricultural production along the Vaal River. It offers benefits including stabilisation of dry land crop production with supplementary irrigation; production during the dry seasons; and a cost-effective method of reducing the additional mine drainage. Increased amounts of water can be made available to the farming community and can be used for irrigation of high-potential soils such as in the coal fields in Mpumalanga Province where water resources are already restricted. A large number of jobs could be developed which would advantage the local community and South Africa as a whole (Frost & Sullivan 2011: 14).

According to Jovanovic, Barnard, Rethman & Annandale (1998: 112), the coal fields in Mpumalanga Province in South Africa underlie one of the most important high potential agricultural areas in the country. “The area in which the coal fields occur is a major catchment for rivers supplying water to the industrial and mining heartland of Gauteng, the national Eskom power grid, important irrigation schemes and the Kruger National Park” (Jovanovic et al. 1998: 112). Most South African coal deposits contain pyritic formations, and when exposed to oxygen, water and iron pyrite they are oxidised to sulphuric acid and iron sulphate. This leads to increased quantities of AMD forming. The high acidity of this water excludes it from being discharged into natural streams, because the environmental impact would then be severe. Disposing mine waste water is an issue and becomes a concern from an ecological viewpoint. If discharged into the natural environment, lime-treated AMD can cause salination of soil, rivers, dams and catchment areas. “Lime-treated AMD has in the past only been used for dust alleviation on dirt roads and irrigation of lawns” (Jovanovic et al 1998: 113). In contrast, Frost and Sullivan (2011: 15) are of the opinion that treated water could be used for irrigation of agricultural crops and for higher potential soils, and “filtering saline water through the soil, and thereby precipitating gypsum in the profile, could limit environmental pollution”. The high costs of AMD treatment could thereby be balanced to some extent by commercial farming’s income (Jovanovic et al. 1998: 113). The use of this lime-treated AMD water could be used for irrigation of agricultural crops and could solve water shortage problems and benefit communities (Jovanovic et all 1998: 119).

According to Opperman et al. (personal interview, 2013), the case in the Blesbokspruit in Gauteng is similar to that in Mpumalanga. AgriSA was not aware of similar cases in the Western basin but in the Wonderfonteinspruit the farmers are now using the treated water. A question of interest that arose from this was that in terms of volume, much water was already being treated and was available for agricultural use but why was it not being used more? AgriSA's response was that the lime-treatment process was being investigated further and could be developed more. Furthermore, some farmers were authorised to use effluent water or could apply for a licence but there were risks involved in using the water. The DWA was also investigating this option (Opperman et al. personal interview 2013).

According to Opperman et al. (personal interview, 2013),

> The perception is that the mines that are responsible for this were around for a very long time and, as part of their operations, they had to dewater and part of their conditions was to neutralise but this was not always done and the water was dumped into the streams and formed part of the Vaal River system. Government had supported these mines through pumping subsidies to keep these mines alive and they had to pump water that seeped in from other mines. The salt load then had to be dealt with. The DWA tried to manage the salinity in the Vaal system but the levels increased and affected the users downstream who had then to manage with these increased salinity levels. The additional water that has to be diluted puts [South Africa's] water resources in dire straits because there is not enough water to do this, especially in Gauteng. In addition to neutralising the water, there are plans to desalinate it with reverse osmosis and this is not to create additional drinking water but to remove the salinity. When irrigating with this water, the plants extract the water component and it concentrates all the salts in the water. If this is done with the neutralised AMD, a significant percentage of salt precipitates and this does not affect the quality of the soil or cause harm to the plants. This will enable up to 50 per cent of salinity being removed and less diluted water is needed.

Thus, from the explanation above, agriculture remains part of the solution to treating acidic affected water.

The social impacts are many and tend to be overlooked completely when AMD is being addressed by government departments. Consultants and activists are more likely to bring to light to what these impacts are and cases where these impacts have occurred, and will fight for a solution. Contaminated water tends to have numerous direct and indirect impacts on society, and they link closely to the environmental impacts mentioned above as well as contamination of land that leaves farming activities unsuitable (Frost & Sullivan 2011: 31). Pollution of farming land by decanted mine water can lead to toxic elements leaking into the soil. This will have an impact on the communities who live nearby, forcing them to relocate and suffer all the inconveniences that come with relocation. Mine water also has effects on different animals. Animals act differently when they come into contact with contaminated water. What is common is that animals suffer miscarriages, deformities and birth defects that affect their joints and cause diarrhoea (Frost & Sullivan 2011: 31).

The research conducted by the WRC is meant to play a crucial role in reducing the negative social impacts that mine water has had in South Africa. There are known cases where land for faming has been lost and peoples' livelihoods have been comprised as the outcome of mine water contamination (Frost & Sullivan 2011: 31). The WRC's research on the use of mine water has benefits for society and include reduced pollution of farming land, which will improve crop production and enhance standards of living; limited polluted surface water, which will increase livestock and household income, which, in turn, will enhance livelihoods and improved quality drinking water, reducing mortality among communities (Frost & Sullivan 2011: 32).

5.5 Conclusion

This objective of this chapter was to identify the instances of the socio-economic impact of AMD. As indicated in the literature review in Chapter 2, the knowledge on this aspect of AMD is rather limited or under-researched. Much more attention is paid to the geoscientific and engineering aspects of AMD. Certain limitations make original research of the socio-economic dimensions exceptionally difficult, such as the ostensible political sensitivity of the matter, the unpredictable cost implications, the negative reputation it can present to the mining business community and foreign investors, and the fear of sensationalism.

The results in this chapter are, therefore, limited. Impacts in the areas of the environment, health, social welfare and economics were identified. Most obvious are the environmental impacts, though their extent is not yet fully known. Tourism appears to be almost untouched by the AMD scare, while the main unknown area is the health implications of AMD and MRAs.

Agriculture presents an important test case that can determine both the impact of contaminated mine water, acid rain, the environmental impact on river systems from which irrigation is done, and the practical agricultural use of treated mine water and the by-products of the treatment process.

In conclusion, this study cannot yet present a definitive assessment of the socio-economic impacts of AMD and, therefore, the need for much more research in this field is identified. Identification of these impacts is partly dependent on how AMD is defined (as discussed in Chapter 3). As a result, huge differences of opinion exist between government officials and the NGO activists about the very nature and impact of AMD.

CHAPTER 6: CONCLUSION

The aim of this study was to investigate and determine from a sustainable development perspective whether the South African government's evolving policy response is sufficiently synchronised or sensitive to the social dynamics of AMD in the Vaal River system. Three objectives were derived from this overarching aim or research problem. The first was directed towards the government's policy response to AMD and how it evolved. The second objective was to determine the socio-economic implications of AMD in the Vaal River system, who are affected by it and how are they affected? Lastly, the objective was to determine whether the emerging policy would be able to address the impact of AMD on society.

The objectives of the study were, to a large degree, concerned with the government's policy and how it addresses the socio-economic dynamics of AMD. Therefore, public policy within sustainable development was used as the theoretical framework on which the study was based. Qualitative methods were used to conduct the research through the use of key informants who were an essential source of information and who contributed significantly to the conclusions of this study. The use of semi-structured interviews allowed for new information to be gathered from the key informants which was used in combination with official documents, media reports and published literature.

The first main conclusion of this study – and also, arguably, one of its important contributions – is conceptual in nature. The manner in which AMD is defined also determines how it is assessed as a water management, environmental and social problem. It also means that the response to AMD is determined by how it is defined. The conventional definition in the literature is that acidic water is formed underground when old mine shafts fill up with water, which oxidises with the sulphide mineral iron pyrite, this then decants into the environment causing AMD. This conceptual understanding of AMD is also embraced by South African government officials. However, during the interviews conducted for this study, new ways of defining AMD were identified. This included acidic and radioactive water that is formed by surface interactions between acid rain and mine dust on the tailings dams. The link between acid rain and acidic mine water was not generally known and hardly referred to as an option or way of defining AMD. A more elaborate definition of acidic mine water that focuses not on the underground mine water, but on the formation of mine residue-induced water contamination above ground is the link between acid rain, uranium mine dust and radioactivity. The result is AMD in the context of the combined effect of radioactive rain water flowing from the mine residue areas, uranium mine dust distributed by wind and underground AMD entering the surface water systems. This study concludes that an effective response to AMD will have to use the latter definition as its point of departure; an approach that is currently not yet used.

In addition to the conceptual aspect, a situational analysis of the occurrence of AMD in the Vaal River system was also required in order to determine the scope and nature of the AMD problem and its impact on South African society. When the study commenced, the media and activists concerned regarded the Western basin as a write-off. The underground water in the basin reached the ECL in 2002 and it has had an impact on the Krugersdorp Nature Reserve, the Tweelopiespruit and also reached the Cradle of Humankind. Numerous media reports predicted that the Cradle would be flooded and tourism would be affected. Pumping of mine water commenced and it was partially treated, which resulted in decanting being stopped, and by the end of 2013 the water level was kept below the ECL. Initially, no aquatic life was found in the water and the wildlife in the Krugersdorp Nature Reserve was affected. After conducting the research and interviewing the key informants, it was found that the Cradle had been affected by an inflow of underground water but it was managed in time. The water was treated and there was no serious threat to the underground caves and fossils. Tourist activity could therefore continue. What is still unknown is the actual quality of the treated water and whether it is fit for human use. Activists believe that the water is not appropriate for human use, yet some state that the water has improved and that by the end of 2013 even aquatic life existed in the water.

With respect to the Central basin, the prediction by the various sources was that the Johannesburg CBD would start decanting by September/October 2013, but by the end of 2013 it had not yet materialised. Early in 2013 the tourist centre Gold Reef City also became a topic of concern. However, after interviews with key informants and with a close watch on media reports it was evident that the water level in the Gold Reef City mine was being managed, had been treated in time and did not reach the ECL. The theme park was therefore not affected as suspected.

When the research began, the Eastern basin was viewed as the basin with the least amount of concern. The problems started in 2011 when pumping at the Grootvlei mine was terminated as a consequence of problems with the ownership and management of the mine. The result was that the water level at neighbouring mines increased rapidly. Therefore, decant in this basin is predicted to start in November 2014 if pumping at Grootvlei is not restored soon. What was identified during the study was that this basin has the largest volume of mine water that needs to be controlled – pumping activity is planned at the Grootvlei mine at Shaft No. 3, but there is major dispute over the ownership of this mine and until this is resolved, pumping activity cannot commence.

This conclusion of this study is that at the end of 2013 the situation appeared not to be out of control. While the Western basin was initially regarded as the most problematic AMD region, by the end of 2013 more uncertainty existed about the Eastern basin, mainly as a result of the Grootvlei management problems, and not because of technical or policy deficiencies.

An uncertain element in this situational analysis is the impact of rainfall. Almost all the key informants referred to the exceptional rainfall in the 2010/11 season and how it had exacerbated the incidences of AMD. While outside the scope of this study, the same happened in March 2014 and dramatically changed the situation in the Western basin. An additional conclusion could, therefore, be that rainfall patterns should be more seriously considered as a potential threat in the assessment of the three basins.

One of the major findings in the study was on the issue of mine ownership, mine closures, abandoned mines: who is responsible for the environmental impact of these mines and who should pay the costs for the environmental rehabilitation of these mines? There is, and always has been, legislation in place to ensure that mining companies comply with rules and regulations, but in reality this proved to be superficial. The government and related departments still have an ongoing process trying to ensure that those who are responsible take ownership for the damages caused. The problem with this approach is that it is time-consuming to identify and find the mining companies that are responsible for the damages caused, because most of them are no longer in existence. The finding is, therefore, that because most of the mining companies that are responsible are not able to pay for the damages it has become the taxpayers' responsibility.

This first objective of this study was to investigate the different responses from government and the measures that were put in place to address the AMD crisis. An important conclusion of this study is that the government sees AMD primarily as an underground mine water issue that needs to be treated and has not yet been looked at from other angles. The additional proposed responses are treatment and removal of the tailings dams and mine residue areas as a means to supplement pumping of underground mine water, thereby removing the additional elements of AMD as defined by the NGOs and some researchers. The government's IMC report was extensively analysed and it was found that the report did not address the socio-economic impacts caused by AMD. From the media reports and the responses from various activists in the field, it is evident that there are indeed negative socio-economic impacts on health, agriculture and South Africa's water systems. Government's focus on pumping of underground water is seen as a short-term solution; the long-term solution has not yet been finalised.

The current policy response also includes chemical treatment of the pumped water which includes management of the sludge residue. Both the treated water and the sludge are either not yet appropriate for human consumption or create new mine residue areas. Exceptional rainfall cannot be accommodated in the current approach and exposes the fact that pumping addresses the symptoms of AMD but does not provide a long-term solution. This is vital as it should address the socio-economic impacts that AMD causes. It should be mentioned that the government's response to AMD is not the only approach, and private companies such as Mintails are engaged in complementary treatment processes such as reprocessing and relocation of tailings dams which are more in line with the alternative definitions of AMD and more targeted towards other socio-economic consequences.

This second objective of the present study was to determine the potential or real socio-economic impacts of AMD. These included the environmental, social, economic and health impacts that contaminated mine water could have on communities who live around the mining areas. In the interviews with government officials, interest groups and some researchers it was found that they did not express serious cause for concern about the socio-economic impacts and this was supported by the fact that government does not pay much attention to these impacts. However, activists believe that the socio-economic impacts are many and very serious. Thus, once again, there are differences in opinion over this between the various role-players.

Agriculture is an extremely important element of society who can become potentially affected by AMD because it is the biggest consumer of water in South Africa. Agriculture's use of water requires a combined consideration of the impact of AMD on both agriculture's environmental dimension (i.e. use of land, water and the atmosphere), and its social and economic dimensions (i.e. production of food for human consumption). It is, therefore, a critical test case of the socio-economic impact of AMD. AgriSA, on behalf of the agricultural sector, does not see AMD as an impending crisis for agriculture. It does not have systematic empirical evidence of the negative impact of AMD on any aspect of the agricultural sector. However, the research came across several case studies that illustrate individual instances of declining production of crops, death of animals and, eventually, farmers who had to abandon their farms.

Given the fact that in the interview AgriSA did not reveal any concern about the possible effects of AMD, while some case studies of the negative effects are available, raises the question of how it can be explained. One possibility is that research into the socio-economic impacts of AMD is in general not encouraged, because the focus is primarily on the geoscientific and engineering research to find a technical solution to the phenomenon. Other forms of research are, arguably, regarded as less of a priority. A second possibility is that AMD is politically too sensitive; it involves the mining sector and foreign investors, and is regarded as a strategic sector of the South African economy. From agriculture's point of view, negative reports about AMD impacts might have negative trade repercussions, similar to the ban on red and ostrich meat for a long period, and restrictions on citrus exports. It is argued that bad news with cost implications or sensationalism should probably be avoided, while any revelation about the socio-economic impacts will possibly have such an effect.

One of the most serious challenges for this study was to determine – in addition to its agricultural effects – other socio-economic impacts of AMD. As already indicated earlier in the literature review, very little literature exists in this field. Most of the evidence is in the form of anecdotal observation or reports. As a result, there are such diverse opinions between the different role-players and, of course, the media exaggerate one minor impact and make it an enormous cause for concern. This is the case, because they have leading activists and NGOs providing them with information illustrating how severe the issue is. What was found was that the intensity of the problem determined how rapidly it would be addressed. However, irrespective of the scale of the impact, the fact remains that even the smallest impact is proof that a larger and more extensive impact is definitely possible. This is what Liefferink and other activists are stressing.

Based on the research conducted for this study, including the interviews with the activists, it can be concluded that at this stage no comprehensive empirical statistical data exist in the public domain on the socio-economic aspects of AMD. In the absence of such data, the approach followed mainly by NGOs is to state that case studies of socio-economic consequences do exist and that they can be extrapolated to make a case for the nature (but not the scope or extent) of the socio-economic impacts. The point of departure of such an approach is that mine water from both the surface and underground is often radioactive, acidic, and rich in sulphates and metals. This mine water is complemented by radioactive uranium particles in the mine dust. From the interviews, it can be derived that the approach then followed by the activists is to concentrate on the socio-economic dimensions most exposed to these elements. They would be the environmental dimension (especially aquatic life), the possible impact on tourism (at the Cradle of Humankind, Gold Reef City and nature reserves), housing (its threat in dolomitic areas to develop sinkholes that will make residential use unsafe in the areas), the economic dimension (including its impact on the mining sector, on the demand for pure water by industries, Eskom, Sasol and others, and on safety in the Johannesburg CBD, both in terms of possible flooding, the safety of building foundations and increased seismic activities) and a wide range of possible health implications.

There are, thus, several arguments that suggest that AMD will have many consequences, but there is also no real evidence available yet about the long-term socio-economic impacts that this could actually have. This is an area that will require more attention in future. As a conclusion, it should be said that the problem that motivated this study in the first instance, namely uncertainty about the impacts of AMD, and especially its socio-economic impacts, could not be completely resolved by this study. The perceptional aspect received much more clarity in this study and it revealed how different stakeholders perceived AMD and its impact. The policy perspective has been investigated in much more depth and lack of alignment between the socio-economic implications of AMD and policy measures are also better demonstrated in this study.

The final conclusion of this study regarding the research question whether the government's policy is sufficiently synchronised or sensitive to the social dynamics of AMD in the Vaal River system is, therefore, a qualified "no". The policy is more informed by geoscientific and engineering considerations than by the requirements of sustainable development. Should the government's policy approach be directed more towards the alternative definition of AMD that also includes the effects of acid rain, uranium mine dust and removal of the tailings dams to a central point, the conclusion would be more positive. Should a long-term policy be developed that includes the options investigated by Aurecon and others, which would improve the quality of treated water, the conclusion would then also be more optimistic.

The following recommendations are identified from this study that should be further researched. The first recommendation is similar to one of the conclusions and that is that more research on the socio-economic impacts with regard to AMD should be conducted in the future to better understand better and to limit the negative impacts that AMD has on health, agriculture, food security and other developmental aspects. The second recommendation is that policy documents on policy-making in general should focus more on the socio-economic impacts. Thus, social scientists should be requested and allowed to become more involved in support of the official processes of policy making, and at the same time there is a need for that type of research in the academic/research environment. The last recommendation is with regard to research methodology; more researchers should take part in direct fieldwork and engage with stakeholders in the form of interviews with government officials and not just depend on literature studies – this study demonstrated the importance of such research.

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