RISK-BASED ASSESSMENT OF ENVIRONMENTAL ASBESTOS CONTAMINATION IN THE NORTHERN CAPE AND NORTH WEST PROVINCES OF SOUTH AFRICA

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ABSTRACT

The commercial mining of asbestos occurred in four Provinces of South Africa (Northern Cape, North West, Limpopo and Mpumalanga). It was initiated in the late 1800's and lasted for over a hundred years into the beginning of this century. As a producer of amphibole asbestos, South Africa far outpaced every other country being responsible for 97% of global production. The last crocidolite mine closed in 1996 and chrysotile in 2002. Anecdotal information concerning environmental contamination as a result of the former mining activities and the improper disposal of mine waste tailings has been reported by a variety of authors. Few comprehensive or systematic surveys have been conducted to date to document this issue and very little quantifiable research has been completed on the communities located in close proximity to the former mine sites to determine the extent of contamination. In 2004-2006 communities were surveyed within the Northern Cape and North West Provinces to determine the extent and severity of environmental contamination. This research developed and applied a methodology to select those communities suspected of environmental contamination, a targeted survey methodology, and a protocol for rapid sample laboratory analysis. A total of 41 communities were initially predicted by the model to be suspected for environmental asbestos contamination. Based on the inclusion of local knowledge, a final 36 communities were selected for a screening-level field assessment, 34 of which were found to contain environmental asbestos contamination at rates ranging from 20 to 100% of the surveyed locations. A total of 1 843 samples of soil and building material were collected in the screening level assessment. One community (Ga-Mopedi) was selected as being representative of the total cohort and a more detailed house to house survey was completed. A total of 1 486 samples were collected during the detailed survey. Results of the detailed survey revealed 26.2% of the homes were contaminated with asbestos containing soil and/or building material. A theoretical quantitative cumulative exposure assessment was developed to estimate the disease burden within the study area population of 126,130 individuals within the surveyed communities resulting in a predicted range of 25-52.4 excess deaths per year from lung cancer and mesothelioma due solely to environmental exposures to asbestos pollution. A

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LIST OF ABBREVIATIONS

AD	Asbestos detected
ACP	Asbestos cement pipe
ACS	Asbestos cement sheet
ACM	Asbestos containing material
ACBM	Asbestos containing building material
AHERA	Asbestos Hazard Emergency Response Act (USA)
AIA	Approved Inspection Authority
AIG	Asbestos Interest Group (community facilitators in the Northern Cape)
APR	Air Purifying Respirator
ARD	Asbestos Related Diseases
ART	Asbestos Relief Trust
ATSDR	Agency for Toxic Substances and Disease Registry
CERCLA	Comprehensive Environmental Response and Compensation Liability Act (USA)
CSS	Conservation Support Services
DEAT	Department of Environmental Affairs and Tourism (now Department of Environment - DEA)
DME	Department of Minerals and Energy
DWA	Department of Water Affairs
EAE	Environmental Asbestos Exposure
ECA	Environmental Conservation Act
EHC	Environmental Health Criteria (International Programme on Chemical Safety
f/ml	Fibres per millilitre
GIS	Geographic Information System
GPS	Global Positioning System
HASP	Health and Safety Plan
HSO	Health and Safety Officer
IARC	International Agency for Research on Cancer
ILO	International Labour Organisation
ISO	International Standards Organisation
KRT	Kalagadi Relief Trust
NAD	No asbestos detected
NAVLAP	National Asbestos Voluntary Laboratory Accreditation Programme (USA)
NEMA	National Environmental Management Act
NIOSH	National Institute for Occupational Safety and Health (USA)
OEL	Occupational Exposure Limit
OHSA	Occupational Health and Safety Act
OSHA	Occupational Health and Safety Administration (USA)
PCM	Phase Contrast Microscopy
PCME	Phase Contrast Microscopy Equivalents
PPE	Personal Protective Equipment
RBCA	Risk Based Corrective Action
SAIOH	South African Institute of Occupational Health
SEM	Scanning Electron Microscopy

TEM	Transmission Electron Microscopy
TWA	Time weighted average
μm	Micrometre or micron
US EPA	United States Environmental Protection Agency
WHO	World Health Organisation

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CHAPTER 1

1. INTRODUCTION, BACKGROUND AND RESEARCH OBJECTIVES

Eschel had been in good health up to May 2004. The diagnosis of mesothelioma was made less than a month before his 25th birthday. He is putting on a brave face, trying to cope with one day at a time. His diagnosis has devastated our family. We do not feel angry anymore but just terribly sad, not just for him but also for the many unexpected parents and young adults whose lives this terrible disease is still going to sadden.[1]

1.1. Introduction

Asbestos is a worldwide occupational and environmental hazard of catastrophic proportions responsible for over 90 000 deaths per year worldwide (LaDou et al. 2001; ILO 1986). It will likely cause millions of deaths worldwide due to its ubiquitous extent in our built environment. The profound tragedy of the asbestos epidemic is that all illnesses and deaths related to asbestos are entirely preventable (LaDou et al. 2001). The world is currently experiencing an epidemic of asbestos related disease (ARD), in particular, mesothelioma. Globally, an estimated 124 million people are occupationally exposed to asbestos with no reliable estimates as to the numbers that are exposed within their non-work environment (Concha-Barrientos et al. 2004, Kazan-Allen 2005). Around the time of peak use in the mid-1970s, approximately 25 countries produced asbestos and 85 countries manufactured asbestos products (Virta 2003). As recent as 2000, 21 countries were still actively mining asbestos (Virta 2002). Historically, occupational exposures have received the most attention in the scientific literature albeit some authors such as Hammons and Huff (1974) and Castleman (1984) did attempt to ring alarm bells regarding the potential impact of environmental pollution from asbestos. There is now a growing interest in environmental exposures due in part to the discovery of grossly contaminated communities and environments such as those in Australia, Italy, the Netherlands, Corsica, Turkey, USA, and South Africa (Baris et al. 1979, 1981; Berman & Crump 1999; Braun et al. 2003; Burdorf et al. 2004; Roelofs 2005; Burdett 2008; Case and Abraham 2008). There is also a growing interest in the relationship between contaminated media and

[1] Taken from, "History of Eschel Lala who was diagnosed with mesothelioma on 27 May 2004." This document was provided by the Asbestos Relief Trust (ART) and the family of Eschel Lala (now deceased). Eschel Lala grew up in Prieska.

corresponding levels of airborne fibres and how these circumstances impact human health (ATSDR 2003; Noonan 2006; USEPA 2007).

This Chapter introduces the justification for and approach to the risk-based assessment of environmental contamination in the former asbestos mining regions of South Africa. A brief introduction to the legacy of asbestos mining in South Africa is presented along with a summary of many of the issues surrounding environmental asbestos contamination. This information is contextualized against a backdrop of worldwide asbestos use and mining activities. A synopsis of the current data, literature and thinking surrounding the issue of environmental exposure is presented with respect to the particular focus of this research. The research objectives and approach are presented in this chapter to guide the reader through the remaining body of work. A literature review is presented in Chapter two and the over-arching methodologies employed are discussed in Chapter three with specific approaches introduced with the results presented in the remaining chapters. The final chapter is a synopsis of the research findings including the need for additional risk-based assessments.

1.2. History of global asbestos mining and use

Asbestos use is reportedly almost as ancient as man's evolution from hunter gatherers with the earliest evidence of use found in wicks for lamps and candles dating to 4 000 BCE (before the Christian era) (Virta 2002; Hillerdal 2004). It was also used in embalming cloths to the Egyptian pharaohs (2 000-3 000 BCE) (Abratt et al. 2004) and later by the Romans, Vikings and Persians during cremation ceremonies (Degiovanni et al. 2004). It was used in Eastern Finland as early as 4 000 BCE in pottery and by 1 500 BCE its use was widespread in Scandinavia (Hillerdal 2004). It is most likely that early asbestos was mined from surface outcrops or shallow deposits. There is anecdotal evidence of Charlemagne's court using asbestos table linens that were burned in the fireplace in order to cleanse them. Marco Polo visited an asbestos mine in China during the 14th century destroying the popular myth that asbestos actually came from woolly lizards "salamander cotton."[2] It was also reported to have medicinal qualities and was often prescribed in the middle ages to treat leg ulcers (Degiovanni et al. 2004). During the 1700s and 1800s the uses of asbestos grew to include numerous other products including paper boards in Italy, insulating materials in engines in the United States, fire protective clothing for fire brigades in Paris and brake linings in England to name just a few (Abratt et al. 2004).

In the late 1800s and early 1900s increasing demand in Europe and the United States resulting from the industrial revolution led to an increase in commercial production and mining of asbestos. Demand waned periodically between World War I and the great depression. However, by World War II, its strategic use as an insulator in ships (fire being a major hazard) saw a huge increase in demand for asbestos products. This demand gained momentum following the war as uses expanded, particularly in the construction industry. During its height of consumption in the mid-1970s approximately 5 million tons per year was being produced worldwide (Tossavainen 2004). Its physical attributes, in particular, its flexibility (it could easily be woven into fabrics and textiles), its tensile strength and insulation properties (chapter two provides a more detailed description of asbestos properties) allow it to be used in a variety of products and applications. Approximately 3 000 commercial products are reported to have contained asbestos (WHO 1986). The most common uses however were for friction products such as brake linings and clutch plates, as insulation (fitted, sprayed and trowelled on) around boiler units, pipes, and as part of building materials such as roofing membranes, mastic, tiles, sheet flooring, asbestos cement products, acoustical and fire proofing protection. For example, the structural steel members of one of the New York World Trade Centre Towers were sprayed with asbestos insulation up to the 40th floor as a fire protection measure (Landrigan et al. 2004). This practice was banned in the U.S. during construction of the first tower in 1971 and the remaining floors and second tower received a different treatment giving rise to speculation that the 9/11 terrorists purposely aimed their planes to impact the building above the 40th floor in order to provoke the collapse. Table 1.1 is a

[2] Salamander Cotton was an early term used for asbestos. The term, "asbestos", is derived from the Greek word, "asbestinon" meaning, "unquenchable."

sampling of some of the commercial uses for asbestos and products that have been known to contain asbestos.

Worldwide consumption decreased steadily from the 1970's to approximately two million tons per year as of 2003 (Virta 2006). The countries primarily responsible for production and consumption are listed in Table 1.2. The decline in consumption is primarily the result of increased knowledge of the health hazards of asbestos exposure and of the introduction of safer alternative products. Despite the decrease in worldwide consumption, commercial asbestos mining continues in a handful of countries with informal mining still occurring in an unknown number of locations.[3] Chrysotile was and is still the most commonly used type of asbestos and accounted for approximately 98 percent of the worldwide asbestos production in 1988. Based on import data for the USA, amosite and crocidolite accounted for about 1 percent each (Virta 2006). In approximately 100 countries, asbestos is still widely used, especially in the construction industry where it is mixed with concrete as a binding or reinforcing agent to form a variety of products including corrugated and flat sheets and pipes. In South Africa, there is an estimated one million plus homes constructed with asbestos cement products (FRIDGE 2002). However due to the increased knowledge of its health effects, asbestos has been banned in approximately 40 countries with numerous others taking the issue under consideration (Leprince 2007).

[3] Noor et al. (2004) has reported on informal mining activities in Pakistan.

Table 1.1: List of selected product types that historically have used asbestos

Product		
Brake linings	Stove top pads	Paint
Boiler insulation	Cork boards	Automobile hood liners
Cement sheet products	Railroad insulation	Mastic
Cement pipes	Laboratory hoods	Shingles
Clutch plates	Artificial fire logs	Tape
Electric heaters	Stove top pads	Rope
Electric hair dryers	Textiles	Ceiling tiles
Wine and beer filters	Joint compound	Ironing board covers
Gaskets	Plaster	Cigarette filters (Kent)
Vinyl floor tiles	Fireboard	Cement
Roof membranes	Caulk	Welding rods
Ship insulation	Attic insulation	Fake snow
Fireproof clothes	Pipe insulation	Jewelry molds
Acoustic boards	Spray on insulation	Fire curtains

Given its ubiquitous nature and properties a wide variety of occupational trades utilized asbestos or came into regular contact with it. Table 1.3 is a list of the common trades with reported occupational exposures to asbestos. Research in the mid 1960's by Mt. Sinai (Dr. Selikoff and associates) identified that insulation workers had a significantly increased risk of mortality from asbestos exposure (Selikoff et al. 1964). This occupational exposure also gave rise to exposures to other workers in the vicinity of asbestos, the so called, "bystanders" disease and household contacts (also defined as a secondary or domestic exposure). A variety of studies identified significant increases in disease and asbestos induced abnormalities among household contacts of asbestos workers (Anderson et al. 1979; WHO 1986).

Table 1.2: Selected asbestos producing and consuming countries in metric tons per year (Virta 2006)

Production		Consumption	
Country	**Tons (2008)**	**Country**	**Tons (2003)**
Russia	1 017 000	China	491 954
China	280 000	Russia	429 020
Brazil	255 000	India	192 033
Kazakhstan	230 000	Thailand	132 983
Canada	180 000	Iran	75 840
Columbia	60 000	Vietnam	39 382
Zimbabwe	50 000	Indonesia	32 284
South Africa	20 000	Japan	23 347
United States	7 000	Mexico	20 085
		Canada	19 781
		South Africa	3 496
		USA	1 134

Initial health concerns, however, focused on the occupational exposures and effects on workers. By the beginning of the 20th century, the medical problems associated with exposure to asbestos were already being reported (Castleman 1996; Abratt et al. 2004). By 1935 asbestosis was widely recognised as a major health threat affecting a large proportion of workers who regularly worked with the material and even those with only short duration exposures (Castleman 1996). Since the 1930's, it was known that asbestos exposure could lead to the development of asbestosis and lung cancer. Nevertheless, "the full horror of asbestos contamination of the environment suddenly became apparent in 1960, with the report that a rare form of cancer (pleural mesothelioma) was rampant in the crocidolite asbestos mining region of South Africa." (Castleman 1996, p. 443). The unrestrained use of asbestos in thousands of common products broadened the at-risk population from tens of thousands of trade workers and their families to millions in the general population throughout the world.

Table 1.3: Common trades with potential occupational exposure to asbestos

COMMON TRADES WITH ASBESTOS EXPOSURE POTENTIAL			
Insulators	Steel workers	Pipefitters	Plumbers
Boiler room tenders	Iron workers	Steel workers	Maritime mechanics
Shipyard workers	Crane operators	Electricians	Carpenters
Drywall finishers	Floor coverers	Painters	Plasters
Masons	Laborers	Construction workers	Boilermakers
Welders	Miners	Sheet metal workers	Railroad workers
Brake mechanics	Refinery workers	Power plant workers	Paper mill workers
Textile mill workers	Steam fitters	Maintenance workers	Demolition workers

1.2.1. Definition of terms and concepts

The term "asbestos" is applied to a group of naturally occurring fibrous, sheet silicate minerals that are found throughout the world. In general and per South African legislation, the term specifically applies to six minerals, commonly referred to as, chrysotile, amosite, crocidolite, anthophyllite, tremolite and actinolite (OHSA 1993 as amended). Numerous other minerals may also occur in a fibrous condition but due to other differences (such as their abundance and physical properties such as tensile strength, poor heat conductivity and chemical resistance); they were not commercially mined and are not included in the definition of asbestos (WHO 1986). Only in very minor exceptions are these other fibrous minerals associated with asbestos related disease, therefore, this issue is not addressed in this research.[4] With respect to the production of asbestos, South Africa produced the three predominant commercial varieties, chrysotile (otherwise known as white asbestos), crocidolite (blue asbestos) and amosite (brown asbestos) with minor production of anthophyllite and tremolite (Virta 2006). South Africa produced approximately 95 percent of the world's supply of amphibole asbestos (McCulloch 2002).

Exposures to asbestos can be classified under four broad categories (generally in decreasing levels of concentration), occupational, bystander or para-occupational, domestic and environmental. This research utilises the following definitions related to asbestos exposure:

- Occupational: exposure resulting from the performance of a task involving contact with asbestos in the workplace
- Bystander or Para-occupational: exposure related to being within the vicinity of occupational tasks involving asbestos in the workplace
- Domestic: household contacts of those employees occupationally or para-occupationally exposed to asbestos
- Environmental: exposure from coming into contact with a contaminated environment or from using a product (as a consumer) that contains asbestos.

Exposure pathways include inhalation of respirable fibres and ingestion due to food, hand and water contamination. Inhalation is assumed to be the primary exposure pathway for environmental contamination identified in this research. The exposure is presumed to be the result of contamination of the environment (as confirmed by this research) resulting from anthropogenic manipulation of the naturally occurring asbestos (NOA) deposits and not directly from NOA.

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[4] Naturally occurring fibrous zeolites, such as erionite, have been examined as a potential causative agent in the development of asbestos related diseases. Their natural occurrence within the geographical limits of this research was not ascertained but their potential as an environmental health concern is not mentioned in the literature for this region and is therefore discounted as a confounding variable in this study. The ability of fibrous zeolites to induce mesothelioma at low environmental doses has been addressed by the WHO 1986; Baris, et al. 1979; and Peterson et al.1984 among others.

1.3. Asbestos production and use in South Africa

Commercial mining of asbestos minerals occurred in South Africa from 1893 until 2002 (McCulloch 2002). At its peak asbestos accounted for only three percent of the value of South African mineral exports. As a supplier of asbestos to the world, South Africa produced 95-97 percent of the world's crocidolite (Australia being the only other exporter), 100% of amosite and it was the fifth largest producer of chrysotile (McCulloch 2002; Virta 2006). From a production standpoint, South Africa rivalled Russia, China and Canada with a maximum output of 380 000 tons in 1977 falling to 163 000 tons in 1985 (Virta 2006, p. 8). Production of asbestos in South Africa remained relatively low and unsteady during the first part of the twentieth century, however, World War II brought about a significant increase in demand for asbestos fibre. Demand again increased in the 1970s and by this time most mines were industrial in nature (no longer worked by small tributors). Production of amosite, crocidolite, and chrysotile each dominated a different time period: amosite between 1938 and 1955, crocidolite from 1956 through 1982, and chrysotile prior to 1938 and after 1982 (Virta 2006). The last amosite mine closed in the mid-1980s, the last crocidolite mine closed in 1996 and by 2000 production of chrysotile had fallen to 12 500 tons per year, ceasing entirely by 2003 (McCulloch 2002; Virta 2006). The milled stockpile of asbestos cement products has been substantially reduced but remained available to consumers (both locally and internationally) until a national ban. Everite, the leading supplier of asbestos cement products in South Africa divested itself of all stocks as of 2003. However, imports from Zimbabwe and Mozambique continued coming into South Africa throughout 2004 (B Gibson 2004, pers. comm., 15 June) and the raw mineral is still legally transported across the country for export at South African ports. Chrysotile comes from the serpentine group of minerals and as such, is chemically different from the amphibole forms of asbestos. It is at present, the only form of asbestos still commercially produced with Russia, China, Canada, Kazakhstan, Brazil and Zimbabwe being the largest producers (Tossavainen 2004).

Asbestos consumption in South Africa was ranked 20th out of a list of the 25 top consuming countries with an estimated consumption of 12 500 tons per year in 2000 (Virta 2006). However, it matched the worldwide average on a per capita basis with consumption of 0.3 kg/year (rank of 15th [range = 0.1-3.7 kg/capita/yr]) in

2000 (Tossavainen 2004). Manufacturing consumption in South Africa decreased by 39 percent from 12 689 tons in 2000 to 7 744 tons in 2002 as a result of switching to asbestos alternatives in the construction materials industry and a decline in local and international demand (FRIDGE 2002). These statistics do not take into account that amount of asbestos not formally traded as a commodity but instead used locally in the construction of roads, buildings and as common fill. Nor does it take into account those fugitive migrations and emissions of fibres from stockpiles, mills, and wastage from tailings dumps and losses from transport that remain in the environment.

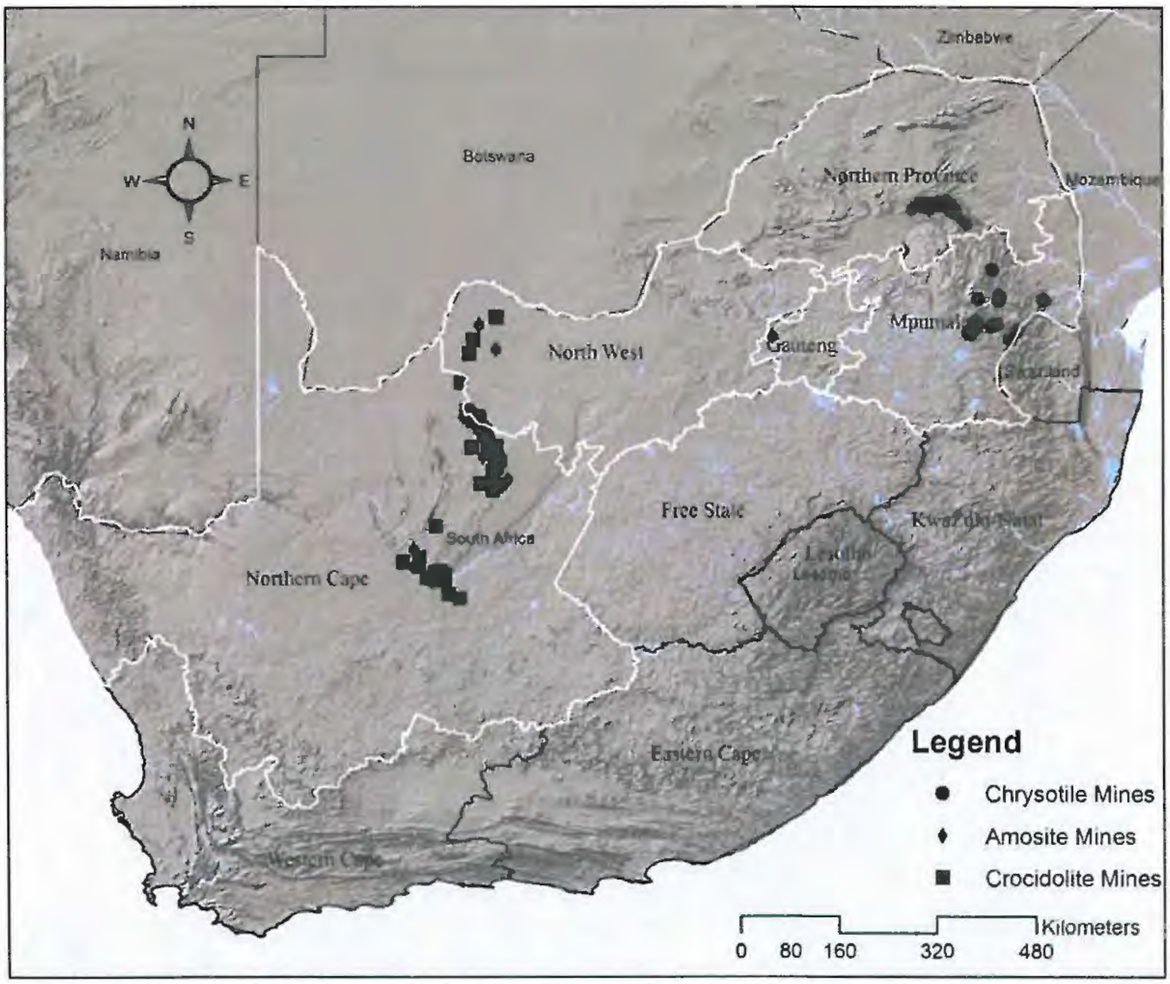

Figure 1.1: Map of asbestos mining regions of South Africa

1.4. Geographic setting of asbestos mines in South Africa

Asbestos mining historically occurred in the Northern Cape, North West Province, Limpopo and Mpumalanga provinces of South Africa. Mining also occurred in

Swaziland just over the border from Mpumalanga and material is still exported through South Africa from the asbestos mines in Zimbabwe. Crocidolite mining historically occurred in the Northern Cape, North West Province and in Limpopo Province and chrysotile was mined in Mpumalanga (Figure 1.1). Mining was initiated in the Northern Cape and North West Province during the late 1800s and continued until 1996. Australia's only crocidolite mine (Wittenoom) closed in 1966. Worldwide concern over the health effects of asbestos, of amphiboles in particular, lead to a decline in demand bringing an end to asbestos mining in South Africa. The mining of amosite asbestos came to a close in 1992, crocidolite in 1998 and chrysotile in 2001 (McCulloch 2002).

Crocidolite mining in South Africa occurred predominantly in the Northern Cape extending into what is now the North West Province. The Cape blue asbestos belt stretches for over 450 kilometres from approximately 25 kilometres south of Prieska to almost the Botswana border with deposits covering an area of several thousand square kilometres. In the Northern Cape, mines were located in the area to the southwest of Prieska (mainly the Koegas mine) extending northward to the region just north of Kuruman running roughly parallel to the former Bophuthatswana Homeland border. In the North West Province, the primary crocidolite mine was located in Pomfret (Bute mine). However, the Provincial boundary closely separates the mines mostly located in the Northern Cape from the adjacent communities in the former homeland (Figure 1.2).

The former asbestos mining regions located in the Limpopo and Mpumalanga Provinces of South Africa (Figure 1.3) encompasses the region from south of Polokwane in the Limpopo Province to those mines located close to the Swaziland border in the Mpumalanga Province. Mining within the Limpopo Province (formerly referred to as the Northern Province and prior to that as the Transvaal Province) occurred principally along an 80 kilometre arc south of Polokwane extending from Lebowakogomo to south of Penge. Crocidolite was predominantly mined in the regions south of Polokwane to Ga-Mafefe (formerly known as the "Pietersburg Asbestos Fields"). Amosite mining occurred near the town of Penge and to a lesser extent at the mines around Ga-Mafefe. In Mpumalanga, the mining region extends from south of Barberton across and into Swaziland (Havelock chrysotile mine). The Msauli mine is located near Diepgezit just inside the South Africa border with Swaziland. Other smaller mines were located near Badplaas and Malelane (see Figure 1.3).

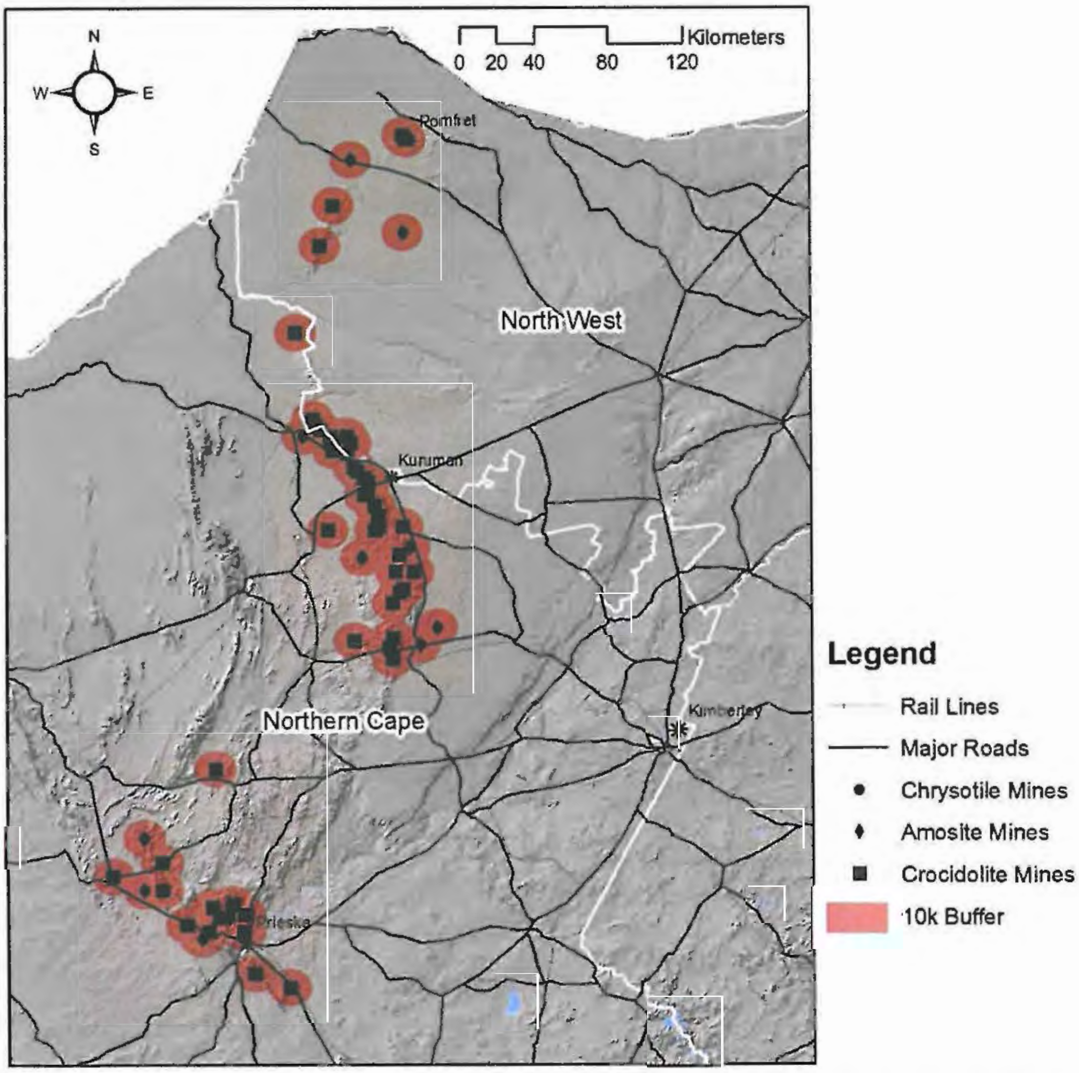

Figure 1.2: Asbestos mining region of the Northern Cape and North West Provinces

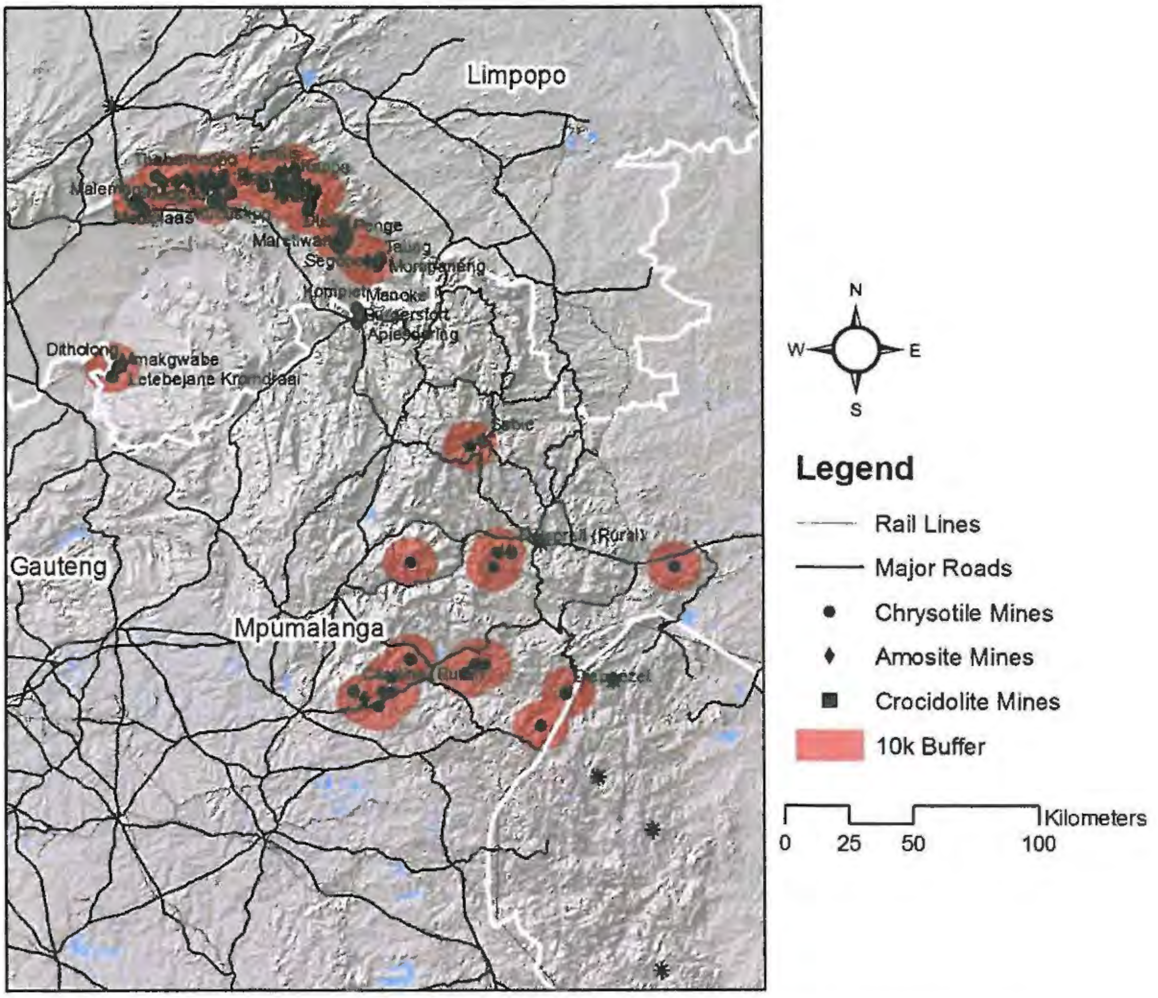

Figure 1.3: Asbestos mining regions of Limpopo and Mpumalanga Provinces

1.5. Gaps in the existing research related to environmental asbestos contamination

Since 1924 occupational exposure to asbestos has been widely researched and well presented in the scientific literature; however, the spectre of environmental asbestos contamination and exposure has not been given equal weight (Castleman 1996). This is likely due to the concern for, and early documentation of, occupational diseases associated with asbestos product manufacturing. The current pandemic of asbestos related disease (ARD) being experienced in the more developed countries is the result of the substantial volumes of asbestos material used in the later quarter of the last century and the latency periods (+/-30 years) associated with ARD (Becklake et al. 2007). The contributory role of environmental exposures to the current disease burden is unclear. While it may be well below the current occupationally related levels in the general population, ARD resulting solely from environmental exposures are difficult to quantify and are poorly reported. Given the much larger population of environmentally exposed individuals the actual disease burdens warrant investigation. In areas of significant environmental contamination the numbers are considerably higher than those reported in the general population. While it is anticipated that the rate of disease resulting from the environmentally exposed population would be low in comparison to a similarly sized occupational cohort, the sheer magnitude of exposed populations gives credence to the issue and the potential numbers of affected individuals.

Much of the continued asbestos mining is done with what is likely, less than stringent environmental controls. With the exception of the Quebec Province of Canada, there is a dearth of documentation as to the nature and extent of secondary contamination caused by the mining and milling of asbestos in the nearby communities. Canada, having more stringent controls and enforcement than many other asbestos mining countries may not be representative of the conditions to be encountered in other parts of the world. The South African context and the conditions encountered in the former asbestos mining regions may be more applicable to other regions such as Kazakhstan, China, India, Zimbabwe and Columbia.

Studies have documented asbestos exposure levels above background rates in asbestos mining regions (Irwig et al. 1979; Sebastien et al. 1979; Sluis-Cremer and du Toit 1980; Selles et al. 1984; Viallat et al. 1991; Rogers and Major 2002). These exposure levels have been linked to correspondingly higher rates of lung fibre burdens in autopsies of individuals living near asbestos mines (Case and Dufresne 1997). Robock et al. (1984) identified airborne concentrations of asbestos in the mining regions of South Africa to be 0.00045 f/ml (analysed by SEM). Studies conducted in South Africa have shown an extraordinarily high level of mesothelioma in birth cohorts that can be attributed to environmental exposures (Zwi et al. 1989; Reid et al. 1990). Reid et al. (1990, pp 586) identified a crude mortality rate of 16.1/1,000 in white females due solely to environmental exposure in the Northern Cape. This compares to estimated background level of 1 in 1 000 000 for the general unexposed population (Lemen 2004). This extremely high incidence rate, attributed solely to environmental exposure, over an extensive geographical area suggests the need for a systematic and detailed risk-based assessment of the contributory environmental conditions.

The industrial exploitation of asbestos, including mining activities, and its use in thousands of products has led to contamination of the general environment in which we live and the air that we all breathe (McDonald 1985) with urbanized ambient air concentrations typically higher than rural regions (McDonald 1985; Sebastien et al. 1979; Singh and Thouez 1985). Chrysotile concentrations have even been measured in the Antarctic and Greenland (Institut National de Santé Publique 2004). In fact, most humans, particularly those who have lived in urban environments have substantial quantities of asbestos bodies in their lungs, though these lung fibre burdens are typically below a level that is thought to induce disease (Weill et al. 2004). The use of asbestos in brake linings, demolition activities and industry is thought to be the leading cause of airborne concentrations of asbestos (Institut National de Santé Publique 2004), hence the greater degree of lung fibre burden experienced by urban over rural residents. These lung fibre burdens contribute to the background levels of asbestos induced lung cancer, mesothelioma and asbestosis to a lesser extent. Hamilton et al. (2004) found high levels of mesothelioma in an urban area without significant industrial sources.

Considerable interest and controversy exists as to the true extent and severity of environmental contamination resulting from the former mining and use of asbestos in South Africa. Articles in the popular press with titles of, *Horror find at Prieska* (Molebatsi 1999), *Asbestos in river raises fears for SA* (Odendaal 2001), *Asbestosis casts its long shadow* (Molefe 2004), *Cloud of asbestos dust blanketed Gencor plants* (Morris 2002), and *Asbestos doesn't rot, it will be there forever* (Morris 2005), among others, fuel the debate over the true extent of environmental contamination. According to the former Minister of the South African Department of Environmental Affairs and Tourism (DEAT), "We also know that it is because of old roads, old buildings, old mines, and cheap construction... that this airborne threat hangs like a cloud over our families..." (van Schalkwyk 2005, p. 1). "The virtually indestructible asbestos fibres can break into thousands of microscopic particles, get released into the atmosphere and thereafter form part of the polluted air people breathe daily. Aided by people's movements, the asbestos fibres can spread up to 100 km radius from the source. Asbestos can be found in building materials used for schools, churches, public offices, homes and brake linings of cars and trucks. The crumbling of roofs and bricks made of asbestos further exacerbates the problem as more fibres are released into the air. The entire Kgalagadi District (former asbestos mining region within the Northern Cape) is virtually covered in asbestos since asbestos is found in public facilities such as clinics, churches, police stations, tribal offices, sports fields, schools and CBDs." (Mabudafhasi 2007, p.1). The true extent and severity of the environmental contamination and its impact on the local communities surrounding the former mine locations are the subject of this research.

Until this research, no comprehensive, systematic studies had been conducted in South Africa to determine the extent and severity of environmental contamination resulting from the mining of asbestos despite its identification as a "significant and sometimes gross pollution" and the lack of "objective measurements" were identified by Sluis-Cremer in 1965 (p. 221). McCulloch (2002) stated that as "once asbestos was disturbed by mining, large areas of the Northern Cape were made permanently hazardous. As fibres move about that hazard has become the centre of an ever-widening circle of risk. "Successive dust storms bring the fibres closer and closer to the major population centres of Gauteng" (McCulloch 2002 pp xvii-iii). While this statement points to the propensity of asbestos fibres to travel long distances on air currents, it bypasses the impact on the local, albeit less dense, communities surrounding the mines. Recent research by Bourdés et al. 2000; Magnani et al. 2003; Pasetto et al. (2005); and Musti et al. (2009) have all identified environmental asbestos exposure (EAE) as a significant threat to the general population within the vicinity of asbestos mines and industry and that sufficient data are not available in many instances to accurately predict the resulting health impacts.

Only two systematic surveys (Felix 1997 and Viridius Technologies (2002) have been conducted to map the extent and severity of contamination outside of the narrowly defined mine footprints. The most comprehensive work completed to date is that by Felix (1997) in the villages of Ga-Mafefe (Limpopo Province). The results are very illustrative for that particular region but the method of determining the extent of contamination was based on verbal questionnaires of current occupants with no sampling or laboratory analysis of the contaminated environmental media (except for air monitoring). This research seeks to emulate that work on a much larger geographical context and with more rigorous sampling and analysis of environmental conditions. Viridius Technologies (2002) completed a systematic survey of selected roads in the Northern Cape (Kgalagadi [now known as the John Taola Gaetsewe District Municipality] and Karoo Districts) including soil and air sampling at regular intervals. This survey was very useful in establishing a relative extent of contamination for this land use, but due to problems inherit in the study methodology, the results are not easily transferable to other similarly contaminated locations.

Exposure assessments and epidemiological studies include Sluis-Cremer and du Toit (1980) who identified 4% of the adult population suffering from indications of environmental asbestos exposure with asbestos dust consistently present in the general atmosphere and fibre present in residential areas. Excess mortality related to asbestos exposure in the crocidolite mining districts of South Africa including "considerable evidence of previous heavy environmental asbestos exposure" was identified by Botha et al. (1986, p.39). A 1998 study (Randeree 1998) of the Prieska area estimated high levels (25-50%) of asbestos related diseases in the communities and described significant and wide-spread environmental exposures in inhabited areas such as schools, playgrounds and homes but provided no estimate as to the total extent of contamination or on the methodology used to characterise the exposures. Mzelini et al. (1999 p.398) identified a 2.8 fold increased risk of mortality in the Northern Province (95% CI = 0.7 to 10.4) in "heavily polluted asbestos areas" with an even higher rate for female residents. REDCO (2007) completed a detailed survey of one community (Prieska) where they completed door to door visual surveys of residences in order to assess the extent of contamination within that community. Anecdotal information exists from Molebatsi (1999), Flynn (2002), Braun et al. (2001), McCulloch (2002), Braun and Kisting (2006) and unpublished sources of extensive environmental contamination in the former mining regions. These are primarily based on eye-witness accounts and interviews of local residents and according to McCulloch (2002) little research has been done in South Africa on the effects of environmental exposure upon health. In addition, with the exception of Felix's work in Ga-Mafefe, the extent of secondary contamination of the environment, in particular, the use of waste asbestos in the construction of homes, schools, roads, and other areas in the vicinity of the mines and mills and to what extent this use is increasing the potential for secondary exposure has not been researched.

ARD incidence rates are pronounced within the Northern Cape and North West Province where as many as 82 abandoned asbestos mines are located (Braun et al. 2003). In addition to the former mine workers, numerous other cases of ARD are being reported and presumed to be the result of secondary environmental contamination from asbestos pollution in villages, waterways, buildings, roads, and dump sites. The Felix (1997) study in Ga-Mafefe (former asbestos mining region) determined that 36 percent of the homes and 53 percent of the public buildings contain asbestos. Total abandoned dump sites, country-wide, are estimated at approximately 580 (Venter 2004). This number does not include sites where environmental contamination extends to schoolyards, playgrounds, roads, gardens and homes. According to the people who live in the communities in close proximity to the former mines, this number underestimates the true scope of unrehabilitated areas (Braun and Kisting 2006). "Once asbestos was disturbed by mining, large areas of the Northern Cape were made permanently hazardous" (McCulloch 2002, xvii).

Based on the above review, it is evident that there are certain deficiencies in the current knowledge surrounding environmental contamination of asbestos in the former mining regions of South Africa. More specifically, these deficiencies are that:

- There is no consistent methodology for identifying, surveying and assessing the existence and extent of secondary environmental contamination resulting from the mining of asbestos.

- There has been no systematic survey completed of the location, condition and exposure potential (severity) from secondary environmental contamination of asbestos.

- There is no documentation of the efficacy of using visual assessment techniques (such as those currently in practice) to identify the extent of contamination.

- There is no risk assessment methodology (risk-based or otherwise) in place to identify and prioritise for remediation those areas deemed as leading to unacceptable levels of asbestos exposure with the term "unacceptable" being highly debatable.

- There is no remediation standard in place, other than the Asbestos Regulations of 2001 that deal with building demolition, to guide remediation of environmental contamination.

1.6. South African governmental strategies

The government of South Africa has accepted responsibility for the clean-up of the environment surrounding derelict and ownerless mines including both the unrehabilitated mine sites and the secondary environmental contamination caused by the previous mining operations. Rehabilitation efforts to date have only focused on the former mining sites themselves, including the more significant and obvious waste disposal sites. However, the more ubiquitous secondary sites may number in the thousands as a result of decades or poorly controlled waste disposal practices, including using waste asbestos in local building materials. Responsibility for rehabilitation outside of designated mining sites lies with the Department of Environmental Affairs (DEA). To date the Department has initiated no remediation of asbestos contamination in the vicinity of the former mine sites but has funded two studies to identify and map the extent and severity of environmental contamination[5]. The existence of asbestos containing building material (ACBM) countrywide is not unique to South Africa and is only addressed as a backdrop to this research. However, the existence, use, condition and potential hazards of

[5] This research has utilised the results of these two investigations which were conducted by the author.

ACBM in the context of the former mining areas are specifically assessed by this study.

The current methodology for mine rehabilitation begins with the identification of the rehabilitation site in consultation with the Department of Minerals and Energy (DME) and through the application of the Rehabilitation Priority Index (RPI). The RPI, using factors such as proximity to populations, wind direction, runoff characteristics and levels of contamination, is used to prioritize those sites for rehabilitation. Those with the greatest potential to negatively impact upon local communities are given priority. This process focuses only on those areas identified as "derelict and ownerless mines" as it has been determined that the DME only has responsibility to rehabilitate the former mining areas and not those areas outside the permitted mine limits. The current methodology focuses on a visual determination of the surface conditions. A trained inspector visually surveys an area looking for the presence of asbestos fibres, fibrous cleavage fragments, or other asbestos debris. Where this debris is visible and directly related to the initial source point (mine or tailings dump), via surface runoff or access, the area is identified as part of the DME's clean-up responsibility. In one case so far, this revised method has led to a substantially larger determination of the impacted area under DME's responsibility.[6] The identified waste dumps are covered by 300 mm of asbestos free soil typically extracted from a nearby source. The slopes are designed to be no steeper than 12 to 18 degrees and may include diversion structures and stone gabions to control surface water movement and minimize soil erosion. The dumps are planted with indigenous, non-edible plants to discourage foraging and grazing by local livestock. The dumps are then monitored for a period of three to five years to assure their integrity. This process is now heavily reliant upon the use of a "visual" assessment technique for the identification of contaminated areas.

The previous method was assessed using a literature review and field sampling in areas of former rehabilitation work in order to determine its applicability to regions beyond the mine limits. Sampling beyond the mine footprints and in areas of

[6] This method has been used at the Bute Mine in Heuningvlei (Northern Cape) and lead to a substantial increase in the "footprint" of contamination resulting in a DME sponsored cleanup proposal of the mine and part of the adjacent Heuningvlei community. No work had been initiated as of January of 2010.

previous rehabilitation identified residual environmental contamination of loose asbestos fibre bundles. The application of the RPI is a significant improvement over the previous efforts but is not directly applicable to land uses other than mining as it does not take into account the continuous exposures that may occur resulting from living, working and recreating in a contaminated environment. A risk-based method was therefore determined to better account for these potential environmental exposures.

From a regulatory perspective within South Africa, asbestos is dealt with as an occupational health risk, though it has been recognised in the literature and by the government as a health risk to the general public[7] (van Schalkwyk 2005). Occupational exposures are controlled vis-à-vis the Occupational Health and Safety Health Act of 1993 (OHSA 2002). This regulation requires a risk assessment to be conducted in industries where exposures may exceed one half of the Occupational Exposure Limit (OEL) of 0.2f/ml over a 4 hour time weighted average (TWA). The risk assessment requirements are spelled out in the Asbestos Regulations of 2001 and are based on the capacity to minimize exposure through the introduction of more stringent engineering controls to reduce airborne emissions and/or the use of personal protective equipment (PPE) such as respirators. This approach is more conducive to an industrial setting where asbestos may be used in the manufacturing process. These standards do not apply to environmental contamination from asbestos as a result of secondary activities (either related to mining or product use). In addition, it does not deal with installed asbestos building materials except for cases of demolition/renovation of structures (OHSA 2002). No standards have been published in South Africa for the assessment of in-place asbestos containing building material (ACBM) or environmental contamination resulting from the uncontrolled use of waste tailings from mining activities. The risks resulting from the abatement of these conditions has also not been quantified and little has been developed internationally to deal with these circumstances (Chrostowski et al. 1991). As the installed material continues to age, its potential to release fibres into the environment will undoubtedly increase (ASTM 2004b).

[7] See as an example the press statement by the Minister of the Department of Environmental Affairs and Tourism (DEAT 2005).

Early reports from the mining sector made scant reference to the occupational exposure of intermittent employees, often woman and their children who accompanied them. Nor did they mention the effect of mining and milling on the local populations. However, documentation produced by the Department of Mines and the Pneumoconiosis Research Unit (PRU) as early as 1963 indicates that the Government of South Africa knew of the dangers of not only occupational exposure, but of environmental exposure to asbestos (McCulloch 2002). In addition, in certain areas of the Northern Cape a large percentage of the population was suffering from asbestos related diseases (ARD) in the early 1960s. This information was never made public in South Africa.[8]

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[8] Specific reference is given to the Pneumoconiosis Research Unit (PRU) *Report on the Progress of Mesothelioma Survey, 1962* as reviewed by McCulloch (2002).

1.7. Research objectives

The objectives of this research were specifically to:

- Develop and apply a contextually specific methodology to assess the areal extent of environmental asbestos contamination within the Study Area (former asbestos mining region of the Northern Cape and North West provinces of South Africa)

- Develop and apply a risk-based assessment methodology that is contextually appropriate to determine the relative risk to the environmentally exposed portion of the Study Area population

- Apply airborne concentrations derived from case studies and field data to the environmentally exposed population in order to estimate the potential disease burden based on the extent of contamination and resulting risk-based assessment methodology

- Validate the risk-based assessment model based on a detailed investigation of one representative community within the Study Area and then assess the model's results in light of other published data for similar conditions within selected representative case studies.

The former asbestos mining regions of South Africa were determined for this research to include initially a nominal horizontal distance of five kilometres from the presumed centre point of the mine sites (as provided by DME). This distance was chosen as the initial criteria for assessing communities though in many cases this distance was exceeded due to locally specific conditions. The series of concentric circles created by the five km buffers were then merged to create the initial survey limits. These were then applied to all five provinces in South Africa were asbestos mining occurred. These locations were assessed by the author but it was determined that this research would specifically report on the application of the methods and results for the Northern Cape and North West provinces though the data for all areas surveyed have been presented to the relevant South African government departments. The resulting Study Area is then comprised of the communities within the Northern Cape and North West provinces that were initially suspected to contain environmental asbestos contamination. For purposes of the cumulative exposure assessment the Study Area was modified to include the populations of the affected Wards. Figure 1.4 is a map of the Study Area utilised for this research.

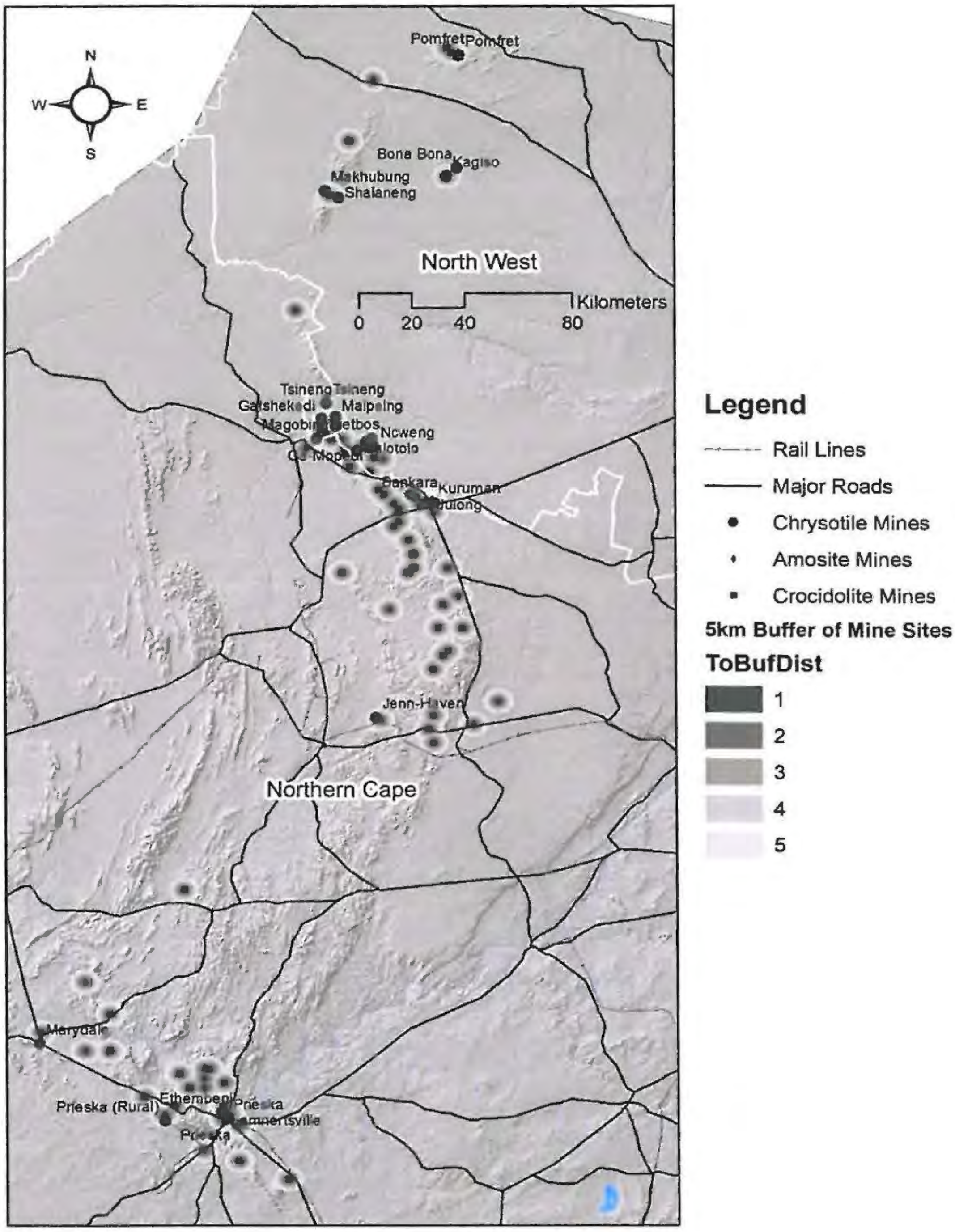

Figure 1.4: Study Area

CHAPTER 2

2. LITERATURE REVIEW

I never worked at a mine but we stayed near a mine dump in Prieska. Now I spend almost the whole day in bed. My movements are very limited and I drink morphine every 4-6 hours for pain. I am still young and the thought of dying is not nice. I have three children and I cannot be a mother for them anymore.[9]

2.1. Introduction

This chapter discusses the physical and chemical properties of asbestos including how they impact upon its virulence as an agent of asbestos related diseases (ARD). In addition, it provides a very brief overview of the major asbestos related diseases, and how the physical properties of asbestos may impact upon the development of an ARD. Current regulatory and policy approaches are discussed, with references to other industrialised and non-industrialised nations. The concept of risk assessment and in particular, risk-based assessment and management is discussed as it applies to this research. The information presented is drawn mostly from scientific and industry literature and government publications. The implications of this information to the specific problems, context, methods, and findings of this research are highlighted where appropriate.

2.2. Properties of asbestos

The following description of the chemical and physical properties of asbestos minerals is presented as background and is adapted from the Environmental Health Criteria (EHC) 53 (WHO 1986) and EHC 203 (WHO 1998) unless stated otherwise. Asbestos is a collective name given to minerals that occur naturally as fibre bundles and possess unusually high tensile strength, flexibility, and chemical and physical durability. Fibre bundles may be several centimetres long and diameters may vary significantly, but tend to be in the millimetre range. When these fibre bundles are manipulated they tend to break down into smaller units, a portion of which have dimensions in the submicron range. The tendency of fibres is to split longitudinally creating fibrils that are long and thin. This particular feature

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[9] Quote from Steph Jansen, 44 – Mesothelioma patient (deceased). Taken from Asbestos's Sorrowful Legacy: A Photoessay. Du Plessis, Hein. IJOEH Vol 9/NO 3, Jul/Sep 2003.

of asbestos is important to this research as it relates to how asbestos is defined, identified, quantified and to how environmental exposures should be assessed.

Fibres, as opposed to particles, are generally considered to have a length to width (aspect) ratio of greater than 3:1 as indicated in the South African regulatory definitions. The following is a definition of a "regulated asbestos fibre" and "asbestos" from the South African Occupational Health and Safety Act (OHSA 1993 as amended by the Asbestos Regulations 2001) (OHSA 2002).

Regulated Asbestos Fibre means a particle of asbestos with a length to diameter ratio of greater than 3 to 1, a length greater than 5 micrometres and a diameter of less than 3 micrometres[10].

Asbestos, in South Africa, is defined as:

Amosite, Chrysotile, Crocidolite, Fibrous actinolite, Fibrous anthophyllite and Fibrous tremolite, or any mixture containing any of [these] minerals.[11]

Asbestos minerals are not classified on a mineralogical basis, but rather on a commercial basis because of their unique properties. For instance, mineralogically, crocidolite is identified as riebeckite and amosite is known as grunerite; the word amosite is actually an acronym of Asbestos Mines of South Africa. All other asbestos types are referred to by their proper mineral names.

The principal varieties of asbestos used in commerce are chrysotile, a serpentine mineral, and crocidolite and amosite, both of which are amphiboles. Anthophyllite, tremolite, and actinolite asbestos are also amphiboles, but they are rare, and the commercial exploitation of all of the amphiboles has now been discontinued. However, tremolite is frequently found as a contaminant of chrysotile asbestos which continues to be mined in several countries. Fibrous mineral silicates are a common constituent of the earth's surface. Other natural mineral fibres that are considered potentially hazardous because of their physical and chemical properties are erionite, wollastonite, attapulgite, and sepiolite. This

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[10] Occupational Health and Safety Act, 1993; Asbestos Regulations, 2001; 1. Definitions

[11] Ibid.

research focuses only on those asbestos varieties commercially mined and most commonly used in South Africa (crocidolite, amosite and chrysotile).

2.2.1. Chemical and physical properties

Chrysotile, which accounts for more than 95% of the world asbestos trade, can occur in virtually all serpentine rocks with deposits currently exploited in more than 25 countries (Virta 2006). Most of these reserves are found in southern Africa, Canada, China, and Russia. Chrysotile, also known as "white asbestos" is a sheet silicate composed of planar-linked silica tetrahedra with an overlying layer of brucite. The silica-brucite sheets are slightly warped because of a structural mismatch, resulting in the propagation of a rolled scroll that forms a long hollow tube. Composites of these tubes form fibre bundles. The chemical composition is uniform in contrast to that of the amphibole asbestos varieties but some trace oxides (Table 2.1) are always present as a result of contamination during the formation of the mineral in the host rock. Some of these trace elements may be structurally accommodated within the tetrahedral site of the silica layer (as in the case of aluminum substituting for silicon), or the octahedral site of the brucite layer (as in the case of nickel or iron substituting for magnesium), or may exist as major elements within minor concentrations of discrete mineral phases intercalated in the fibre bundle (e.g., magnetite).

Chrysotile fibrils are long, flexible, and curved, and they tend to form curvilinear bundles with splayed ends. They naturally occur in lengths varying from 1 to 20 mm, with occasional specimens as long as 100 mm. They are considerably more susceptible to acid decomposition than the amphiboles; this being a contributing factor in its more rapid clearance from the body (discussed in Section 2.4). The fibres are pale green to white and are typically curly and soft. Under the microscope they are readily identified by their optical characteristics (McCrone 1985).

The amphibole minerals are double chains of silica tetrahedra, cross-linked with bridging cations without the hollow central core typical of chrysotile. Magnesium, iron, calcium, and sodium are the principal cations in the amphibole structure. Specific physical properties are summarized in Table 2.1. The amphibole structure allows great latitude in cation replacement therefore the chemical composition and physical properties of various amphibole asbestos fibres cover a wide range. Only rarely does the composition of a field sample coincide with the assigned theoretical or idealized formula (this being an issue with respect to laboratory analysis). However, theoretical compositions are used for identifying the various fibres as a matter of convenience. The specific determinations as to the type of amphibole asbestos, requires the use of x-ray diffraction techniques to adequately characterize the samples by their proper chemical signature. This can be problematic, as it requires the use of expensive laboratory equipment, trained and experienced technicians and appropriate sampling and analysis protocols which are not commonly employed in South Africa. These methods are also not easily accessible in many of the countries where asbestos has been or continues to be mined and utilised. These issues of "technical capacity" influence the methods and techniques used to quantitatively assess for environmental contamination (see discussion in Chapter 3).

Amphiboles tend to separate along defined crystallographic planes (both parting and cleavage) leading to fibrils of 4.0 nanometres in diameter (Langer and Nolan 1985 as quoted by WHO 1986). "These mechanisms of amphibole breakage are important biologically with regard to resultant particle number, surface area, and general respirability (all of which control penetration to target cells and delivered dose), and also with regard to expressed chemical information contained on the fibre surface (Harlow et al. 1985, as quoted by WHO 1986 pp. 2.1.2). In a crystallographic study of amosite asbestos and its physically-different counterpart, grunerite, size distributions were different when they were comminuted in an identical manner. This factor controls both quantity and quality of dose (ibid).

The name "crocidolite" is derived from the Greek words "Krokis" meaning woolly and "lithos" for rock and is attributed to the German Geologist Hausman who in 1831 used it to describe what was then simply referred to as "Woolstone" (Abratt et al. 2004). It was first discovered in South Africa in 1805 but commercial mining did not begin until the late 1800s (McCulloch 2002). Typical crocidolite (Riebeckite) fibre bundles easily disperse into fibres that are shorter and thinner than other amphibole asbestos fibres, similarly dispersed. However, these ultimate fibrils are generally not as small in diameter as fibrils of chrysotile. In comparison with other amphiboles or chrysotile, crocidolite has a relatively poor resistance to heat, but its fibres are used extensively in applications requiring good resistance to acids. Crocidolite (blue asbestos) fibres have fair to good flexibility, fair spinnability, and a texture ranging from soft to harsh.

Amosite (Grunerite) fibrils are generally larger than those of crocidolite and chrysotile, but smaller than particles of anthophyllite asbestos similarly comminuted. Most amosite fibrils have straight edges and characteristic right-angle fibre axis terminations. The light grey to pale brown mineral is also referred to as "brown asbestos" and it is occasionally contaminated with fibres of actinolite. It was first mined at the turn of the twentieth century and occurs mainly in the area of Penge within the Limpopo Province of South Africa. It is the largest deposit of amosite in the world occurring over a 40 km distance as part of the *Pietersburg asbestos fields* (Abratt et al. 2004). Table 2.1 identifies the major physical and chemical properties of the six types of asbestos (adapted from WHO 1986).

2.3. Asbestos Related Diseases (ARD)

The occurrence of asbestos related disorders are among the most published of topics in occupational and environmental health including a number of multidisciplinary gatherings of medical and environmental/occupational health scientists. These include the United Nations World Health Organisation's (WHO) International Agency for Research on Cancer (IARC), the International Programme on Chemical Safety (IPCS) Environmental Health Criteria (EHC 53, 1986 and EHC 203, 1998 [chrysotile])[12] publications and a variety of governmental agencies in North America and Europe including the U.S. Environmental Protection Agency (EPA), the U.S. Agency for Toxic Substances and Disease Registry (ATSDR) and the British Environmental Health Commission (EHC).

The toxic properties of asbestos have undergone both general and specific causation analysis over many decades (Concha-Barrientos et al. 2004). General

[12] The International Programme on Chemical Safety (IPCS) is a joint venture of the United Nations Environment Programme, the International Labour Organisation, and the World Health Organization.

causation involves a determination of whether a particular substance causes the effect being studied whereas specific causation attributes an individual's disease to exposure to the substance (Lemen 2004). General causation involves a review of mechanistic processes, biological principles, molecular studies, toxicological studies, animal experimentation, and human epidemiologic studies. Epidemiological studies can include case reports, case-control studies, cohort studies, and mortality and morbidity studies. Varied risk coefficients have been estimated from approximately fifteen epidemiology studies for which adequate dose-response data exists (Berman and Crump 1999). Historical measures of asbestos concentrations used in the aforementioned epidemiology studies may not reflect the characteristics of asbestos exposure that ultimately determine risk (ibid). These characteristics include fibre size, morphology and concentrations and are discussed in more detail in Section 2.4 of this study.

Table 2.1: Physical and chemical properties of common asbestos minerals[a]

CHARACTERISTIC:	CHRYSOTILE	CROCIDOLITE[b]	AMOSITE[c]	ANTHOPHYLLITE[d]	TREMOLITE[d]	ACTINOLITE[d]
Theoretical formula	$Mg_3(Si_2O5)(OH)$	$Na_2FeII_3FeIII_3(Si_8O_{22})$	$(Fe, Mg)_7(Si_8O_{22})(OH)_2$	$(Mg,Fe)_7(Si_8O_{22})(OH)_2$	$Ca_2Mg_5(Si_8O_{22})(OH)_2$	$Ca_2(Mg,Fe)_5(Si_8O_{22})(OH)_2$
Chemical analysis (range of major constituents (%))						
SiO_2	38-42	49-56	49-52	53-60	55-60	51-61
Al_2O_3	(0-2)[e]	(0-1)	(0-1)	(0-3)	(0-3)	(0-3)
Fe_2O_3	(0-5)	13-18	(0-5)	(0-5)	(0-5)	(0-5)
FeO	(0-3)	3-21	35-40	3-20	(0-5)	5-15
MgO	38-42	(0-13)	5-7	17-31	20-25	12-20
CaO	(0-2)	(0-2)	(0-2)	(0-3)	10-15	10-13
NA_2O	(0-1)	4-8	(0-1)	(0-1)	(0-2)	(0-2)
N_2O+	11.5-13	1.7-2.8	1.8-2.4	1.5-3.0	1.5-2.5	1.8-2.3
Colour	Usually white to pale green, yellow[f], pink[f]	Blue	Light grey to pale brown	White to grey to pale brown	White to grey	Pale to dark green
Density (G/CM3)	2.55	3.3-3.4	3.4-3.5	2.85-3.1	2.9-3.1	3.0-3.2
Resistance to acids	Undergoes fairly rapid attack	Good	Attacked slowly	Very good	Very good	Attacked slowly
Resistance to alkalis	Very good	Good	Good	Very good	Good	Good

CHARACTERISTIC:	CHRYSOTILE	CROCIDOLITE[b]	AMOSITE[c]	ANTHOPHYLLITE[d]	TREMOLITE[d]	ACTINOLITE[d]
Texture	Usually flexible, silky and tough	Flexible to brittle and tough	Usually brittle	Usually brittle	Usually brittle	
Main countries of production	Canada China Italy South Africa Swaziland USA Former USSR Zimbabwe	South Africa	South Africa	Mozambique USA	Italy USA	

[a] Table 2.1 modified from WHO 1986
[b] Mineralogical name of crocidolite is riebeckite.
[c] Mineralogical name of amosite is grunerite.
[d] Anthophyllite asbestos is the proper term, as with tremolite and actinolite.
[e] Bracketed figures denote common elemental substitution found in asbestos minerals.
[f] From serpentinized dolomite deposits.

Epidemiological studies, mainly on occupational groups, have established that all types of asbestos are associated with diffuse pulmonary fibrosis (asbestosis), pleural fibrosis, bronchial carcinoma (lung cancer), and primary malignant tumours of the pleura and peritoneum (mesothelioma) (WHO 1986 and 1998; USEPA 1986b; Berman and Crump 1999; ATSDR 2001). That asbestos causes cancers at other sites is less well established. Gastrointestinal and laryngeal cancers are possible, but the causal relationship with asbestos exposure has not yet been firmly established and there is also supporting evidence for cancer at other sites but these have not been as widely reported. A detailed discussion of the various types of cancers associated with asbestos exposure is beyond the scope and does not bear directly on the results of this research.

There is still considerable debate over the mechanistic processes of ARD and in particular, the role of fibre morphology and size as contributing factors. Much of this debate is beyond the scope of this dissertation and is only briefly highlighted where pertinent. All six varieties of asbestos (as defined by South African legislation) are Group 1 carcinogenic agents per the International Agency for Research on Cancer (IARC 1987). As recently as 2009 asbestos (chrysotile, crocidolite, amosite, tremolite, actinolite and anthophyllite) was reconfirmed by the IARC as carcinogenic with sufficient evidence to support cancer induction of the lung, mesothelioma (pleura and peritoneum), larynx, and ovaries and supporting evidence for colorectum, pharynx, and stomach (IARC 2009). A review of published literature was undertaken by the National Academy of Sciences (2006) and determined that there was sufficient evidence to support asbestos as causal for laryngeal cancer, suggestive but not sufficient for stomach, colorectal, and pharyngeal cancers and insufficient to link it to esophageal cancer (NAS 2006).

Asbestos related diseases (ARD) are thought to have a "linear dose-response" relationship which indicates that as dosage increases so do the risk of contracting disease (ATSDR 2003). This also indicates that there is no lower threshold of exposure where risk of disease is zero. Cigarette smoking increases the asbestosis mortality and the risk of lung cancer in persons exposed to asbestos but not the risk of mesothelioma. The synergistic effect of smoking and asbestos exposure is poorly understood, but the increased chances of contracting lung cancer as a result are well documented and may be up to 20 to 50 times greater than that found in background populations and much greater than the sum of the two risk factors (ATSDR 2001).

The following is a brief description of the major illnesses linked to asbestos exposure taken from these various consensus reports and recent literature as noted with a particular emphasis on environmental (as opposed to occupational) exposures.

2.3.1. Asbestosis

Asbestosis is a disease of the lungs that is classified as a pneumoconiosis, (diffuse interstitial fibrosis), also referred to as "white lung". The disease manifests itself from scarring from fibrotic collagen deposits that build over time reducing the lungs elasticity and its ability to pass oxygen molecules (ATSDR 2001). Symptoms include shortness of breath (dyspnoea), accompanied by coughing, wheezing and rales (Churg 1986; ATSDR 2001). Asbestosis results in decreased pulmonary function which becomes more debilitating over time, even after exposure has ended which can ultimately lead to death. A number of studies have documented excess mortality from asbestosis in a variety of occupationally exposed cohorts (Selikoff et al. 1979; Peto et al. 1985; de Klerk et al. 1991) including South African asbestos miners (Sluis-Cremer 1965; Sluis-Cremer et al. 1984).

Exposure levels necessary to induce asbestosis have been determined based on a large number of epidemiologic and animal inhalation studies. As compared to asbestos related cancers, asbestosis results from relatively high levels of dust exposure such as those formerly found in occupational settings (asbestos manufacturing operations, mills, mines, textiles plants, insulation, shipyards, etc). However, as occupational exposures have been reduced through more stringent regulation and the threat of liability, the prevalence of asbestosis will eventually be reduced due to the latency period of the disease. According to the U.S. Census Bureau, rates of asbestosis deaths in the U.S. have continued to climb with less than one death per million reported in 1968 to over 6.9 per million in 2000 with a slight decline from 2000 to 2004 (Mazurek and Wood 2008). Selected cumulative occupational exposure levels (the product of exposure multiplied by intensity) associated with asbestosis are shown in Table 2.2.

Table 2.2: Selected occupations and reported cumulative exposure levels*

OCCUPATION	FIBRE-YEARS /ML
British asbestos textile workers	38 f-yr/ml (BOHS 1983)
Indian asbestos cement workers	62 f-yr/ml (Dave et al. 1997)
British Columbian chrysotile miners and millers	30 f-yr/ml (Enarson et al. 1988)
South Carolina chrysotile textile factory workers	22 f-yr/ml (Green et al. 1997)
Swedish asbestos cement workers	20 f-yr/ml (Jakobsson et al. 1995; Wollmer et al. 1987)
South African crocidolite and amosite miners	70 f-yr/ml (Irwig et al. 1979)
South African crocidolite & amosite miners & millers	15 f-yr/ml (Sluis-Cremer 1984)

*Source: Adapted from WHO EHC 1986 and ASTDR 2001

The use of cumulative exposure as a surrogate exposure metric in the available studies requires the assumption that duration and intensity are equally important in determining the effective dose (Finkelstein 1995). He further noted that if exposure estimates are inaccurate or inconsistently measured (which can be the case for many retrospective epidemiology studies), a finding of a statistically significant association between cumulative exposure and a health outcome can mislead one into having confidence in an apparent exposure-response relationship that is principally influenced by duration of exposure and not by exposure intensity.

A review of the epidemiological evidence for asbestosis exposure-response relationships (as part of the WHO report of 1998) concluded that "asbestotic changes are common following prolonged exposures of 5 to 20 f/ml" (these correspond to cumulative exposures of 50–200 f-yr/ml for a 10-year exposure) and that at lower levels the risk is undetermined. The WHO (1998) further stated that the risks at current levels of occupational exposure (to chrysotile) are unlikely to lead to clinical manifestation even though they may induce respiratory changes (WHO 1998). Stayner et al. (1997) predicted, by extrapolation, an excess lifetime risk of 2/1,000 for asbestos mortality in white men exposed for 45 years at the current U.S. Occupational Safety and Health Administration's permissible exposure level of 0.1 f/ml (4.5 f-yr/ml).

However, dose-response relationships at non-occupational levels of exposure can still lead to substantially increased rates of mortality, especially with respect to amphibole asbestos as evidenced in Libby, Montana and potentially within South Africa. According to Whitehouse et al. (2008) 66 percent (77/116) of patients who died of non-malignant asbestos related disease treated at the Centre for Asbestos Related Disease (CARD) clinic were environmentally or domestically exposed to asbestos (Libby Amphibole). Furthermore, death rates were similar between what were assumed to be heavier occupational exposures and much lower environmental exposures. According to Whitehouse, "there are many examples in a patient cohort of surprisingly minimal exposures which led to significant disease." (Whitehouse 2008, pp. 28).

Within South Africa there is a paucity of data with respect to environmental/domestic exposures resulting in the development of ARD. According to the 2009 Annual Report of the Asbestos Relief Trust (ART), a total of 138 claims for environmental exposure to asbestos leading to the development of an ARD have been submitted to date (ART 2009). The Kgalagadi Relief Trust (KRT) had processed 89 as of 2009. Of the 89 submitted to the KRT, 19 were approved (the patient was verified to have an ARD qualifying for compensation and they met the Trust's criteria for the burden of proof that it was caused by an environmental exposure (KRT 2009). Of the 40 approved by the ART to date, 15 were diagnosed with asbestosis (ARD1 or ARD2), or 38 percent (ART 2009). These results should be considered in light of those discovered by Felix (1997) (see Chapter 1) wherein 34 percent of the total population of Mafefe was found to have radiographic abnormalities resulting purely from environmental exposure. This compares to only 18 percent of the general population screened in Libby (n = 6 668) that included occupational and environmental exposures (Whitehouse 2008). Khan et al. (2004) has reported proportions of 0.5% to 8% for pleural abnormalities within the general population from environmental exposures. Khan et al. (2004) also reports that the development of pleural plaques depends on the length of exposure or the time since the exposure occurred and not on a threshold dose which he reports is required for asbestosis. The prevalence of pleural plaques is 10% in exposed individuals 20 years after first exposure, rising to 50% after 40 years from the date of first exposure (Khan et al. 2004).

The notion of an apparently high threshold value for asbestosis is being challenged by the results from environmentally exposed populations such as those found in Libby, Montana and the Study Area wherein the diagnosis of asbestosis is common amongst the environmentally exposed population. These results seemingly contradict the prevailing notion found in the literature that asbestosis is declining and will continue to decline in the general population as more stringent occupational controls are put into place. While this may hold true for the general working population, it is apparently not applicable to those environmentally exposed to asbestos in Libby, Montana or South Africa.

All types of asbestos can lead to asbestosis and both long and short fibres have been implicated with a tendency towards the longer fibres having greater fibrotic activity (Churg and Wiggs 1986; Churg and Wright 1989; Churg et al. 1990; Churg and Wright 1994; Churg et al. 2000). A more recent study by Nayebzadeh et al. (2006) suggests fibre length may be less important than type. Asbestosis can be detected with a lung x-ray and assessed by a lung function test. The latency period for asbestosis appears to be dose dependent with an inverse relationship. Those individuals with asbestosis are also thought to be at a greater risk for contracting other asbestos related diseases such as lung cancer (Weiss 1999).

2.3.2. Lung Cancer

Lung cancer, or carcinoma, is also related to asbestos exposure. Lung cancer occurs when certain cells in the lung start to divide uncontrollably. The "growth" can reduce lung function and the cancer cells can also enter the bloodstream and move to other parts of the body. Lung cancer is fatal in many cases, especially if not caught in its early stages. Asbestos related lung cancers have historically been associated primarily with occupational exposures. Selikoff et al. (1979) followed a cohort of asbestos exposed insulation workers (17 800) in the U.S. and Canada and determined that lung cancers were 4.6 times higher than the rates expected in the general male population. Similar findings have been reported in a number of studies conducted under a wide variety of occupational exposure settings (ATSDR 2001). Lung cancer can occur with low levels of exposure, such as those that occur in the general environment (non-occupational) with lung cancer reported in household contacts and family members of asbestos workers, presumably carried home on the work clothes, (Anderson et al. 1979). Higher lung cancer rates are linked to all three types of commercially mined asbestos, though there is evidence of a differing carcinogenicity between fibre types.

Smoking is one activity that substantially increases the risk for lung cancer. Smokers are already subject to an elevated lifetime risk for developing lung cancer (10 to 20 times greater than non-smokers) (U.S. Dept of Health and Human Services 2004). However, smokers who also are exposed to asbestos increase their chances of lung cancer by a factor of 10 (more than just adding the two risk factors together) due to a supposed synergistic effect between tobacco smoke and asbestos fibres (EPA 1986a). The latency period for lung cancer is estimated at 10-40 years in humans (ATSDR 2007a). This is the period of time from first exposure to the onset of an asbestos related disease. Cumulative risk increases with exposure (linear dose-response relationship) with excess risks of 10E-7 to 10E-4. A cumulative exposure of 0.035 f-yr/ml (for smokers) and 0.35 f-yr/ml for non-smokers represent an increased risk of 10E-4 (1 in 10 000) as estimated by the EPA (1986a). It is interesting to note that these estimates are considered by some to be overly conservative (Lash et al. 1997) by 4 to 24 times, however, Hodgson and Darnton (2000) notes that if you remove chrysotile miner and miller data from the risk estimates and assess only the amphiboles, the slope of the exposure-response relationship is higher. Camus et al. (1998) reported statistically significant increased risk of lung cancer in women living in the chrysotile mining regions of Quebec therefore suggesting that environmental exposure relates to a lower exposure-response relationship at least for chrysotile. This raises the question of whether different exposure-response curves are appropriate for occupational versus environmental exposures and if they should be differentiated between amphiboles and chrysotile as suggested by Berman and Crump (1999). This issue has relevancy to this research in that one, the majority of the regions where asbestos mining occurred, with the exception of Mpumalanga Province) were amphiboles producing regions (including the entire Study Area) and two, the primary type of exposure of concern is environmental.

It is certain that inhalation of asbestos can lead to increased risk of lung cancer and mesothelioma. This has been conclusively demonstrated in numerous studies of occupationally exposed workers, and has been confirmed in a number of animal experiments. For lung cancer, the magnitude of the risk appears to be a complex function of a number of parameters, the most important of which are the:

(1) level and the duration of exposure;
(2) time since exposure occurred;
(3) age at which exposure occurred;
(4) tobacco-smoking history of the exposed person; and
(5) type and size distribution of the asbestos fibres (ATSDR 2007a)

The last parameter is of special practical importance, since the variability in potency among fibres means that cancer risk from asbestos exposure may vary widely from location to location. Some of this variation may be attributable to differences between the mineral types, but fibre size (length and thickness) appear to be of prime importance as well. Within the Study Area, the vast majority of environmental contamination results from amphibole asbestos thus differences in carcinogenicity are relevant to this research. There is strong evidence from animal inhalation studies that long fibres are more carcinogenic than short fibres. However, this should not be construed to mean that shorter fibres are totally without carcinogenic potency. The relation between fibre size and carcinogenicity may vary between lung cancer and mesothelioma, but this is not yet clear. There is some evidence from animal studies that asbestos-induced lung cancer stems from regions in the lung with advanced fibrosis (asbestosis); however, lung cancer with chrysotile was also produced at fibre concentrations that did not lead to detectable fibrosis (ATSDR 2007a).

2.3.3. Malignant Mesothelioma

Malignant mesothelioma is a disease of the lining of the thoracic cavity (pleural) or abdominal cavity (peritoneal). It is almost always associated with exposure to asbestos. In fact, it is called a "marker" disease because epidemiological evidence has clearly linked mesothelioma to asbestos exposure. The amphibole types of asbestos may be more likely to lead to mesothelioma but all three commercial varieties have been linked to this disease. Many sources of chrysotile also contain varying amounts of amphibole fibres (primarily tremolite) thereby increasing their danger level as well. The latency period for malignant mesothelioma is estimated at greater than 25 years with many studies placing it at 30-40 years. In a review of 1,105 cases of malignant mesotheliomas associated with occupational exposure to asbestos, Lanphear and Buncher (1992) reported that 99% had a latent period >15 years, and calculated a median latent period of 32 years. Symptoms include, pain in the chest or lower back, coughing up blood (hemoptysis), difficulty in swallowing (dyphagia), nausea or anemia and difficulty in breathing (dyspnea). However, often symptoms do not manifest themselves until the disease is at an advanced stage. It can only be confirmed through a biopsy and is almost always fatal. In contrast to the situation for lung cancer, the risk of mesothelioma does not appear to be increased by smoking (Hammond et al. 1979).

Generally, cases of malignant mesothelioma are rapidly fatal with an average time from diagnosis to mortality of 5.9 months with a range 0-34.3 months for the U.K. (Edwards et al. 2000). Other reports place the median survival rate at slightly less than one year (Okello et al. 2009). The observed incidence of these tumours, which was low until about 30 years ago, has been increasing rapidly in males in industrial countries. As asbestos-related mesothelioma became more widely accepted and known to pathologists in western countries, reports of mesothelioma increased. The incidence of mesothelioma prior to 1960 is not known and it is at this time that it was linked to asbestos exposure (Wagner et al. 1960). Mesotheliomas have seldom followed exposure to chrysotile asbestos only. Most, but not all, cases of mesothelioma have a history of occupational exposure to amphibole asbestos, principally crocidolite, either alone or in amphibole-chrysotile mixtures. Chrysotile is widely reported by the asbestos industry as having an, "extremely weak association" with respect to the induction of mesothelioma (Yarborough 2006). In fact, there is generally consensus that it is considerably less potent than the amphiboles, however, Yano et al. (2001), Suzuki et al. (2004) have all reported specific correlations between amphibole free chrysotile exposure and increased rates of mesothelioma in industrially exposed populations.

During 1999--2005, a total of 18 068 malignant mesothelioma deaths were reported in the United States; 14 591 (80.8%) occurred among males and 17 180 (95.1%) among whites. Mesothelioma deaths were classified as mesothelioma of pleura (1 572; 8.7%), peritoneum (657; 3.6%), other anatomical site (2 605; 14.4%), and unspecified anatomical site (13 454; 74.5%). Mortality increased with age, with the greatest number of decedents aged ≥75 years; 311 deaths (1.7%) occurred in persons aged ≤44 years. From 1999 to 2005 the total number of malignant mesothelioma deaths increased 8.9%, from 2 482 in 1999 to 2 704 in 2005, but the annual death rate was stable (14.1 per million population in 1999 versus 14.0 in 2005) (CDC 2009). The death rate for males was 4.5 times that for females (23.2 versus 5.1 per million) (Bang et al. 2009). The comparable rate for South Africa (country-wide) was reported by Zwi et al. (1989) at 33 per one million population per year. Within Western Australia's region of previous asbestos mining activity the reported rate was 66 per million (Whitehouse 2008). Within the 10 mile (16 km) radius from the Town of Libby, Montana, the calculated rate was reported at 166 per million per year (Whitehouse 2008).

Because of the large number of variables, it is difficult to make reliable predictions of the magnitude of the cancer risk that may result from exposures of the general population to asbestos levels that are likely to be encountered outside the workplace. Although there is considerable uncertainty in the estimates, EPA calculated, using a linear, non-threshold model, that lifetime exposure to asbestos dust containing 0.0001 fibres >5 μm in length per ml of air could result in about 2–4 excess cancer deaths (lung cancer plus mesothelioma) per 100,000 people (all types of asbestos). While lung cancer and mesothelioma are generally associated with chronic exposure to asbestos, there are several studies that indicate that short-term exposures are also of concern. For example, it has been noted that workers exposed to asbestos for only 1–12 months had an increased risk of developing lung cancer a number of years later. In animals, mesotheliomas developed in two rats exposed to high concentrations of amosite or crocidolite for only one day. These data are not extensive enough to define the dose or time dependency of health risks from short-term exposure to asbestos, but the data do indicate that short-term exposures should not be disregarded (ATSDR 2001). There is no evidence to support a threshold level below which the risk of mesothelioma is naught. Low level exposure more often than not contains short duration peak concentrations which can be very high (Hillerdal 1999). This also has implications for estimating cumulative exposures. There is no proof of the often cited background level of mesothelioma occurring in the absence of exposure to asbestos (1-2 per million per year), and this "natural level" is probably much lower (Hillerdal 1999, p. 1).

2.3.4. Other Asbestos Related Diseases

The following information is largely obtained from a synopsis of the current literature as reported by the ATSDR (2001) and the IARC (2009) unless specified otherwise. Other types of cancer have been associated with asbestos exposure as well. These include cancer of the throat, stomach, colon, ovarian and intestines. However, the links between these diseases and asbestos are not as well established as for the other diseases discussed above. The chances of contracting an asbestos related disease are the greatest from exposure through inhalation of asbestos dust, therefore, it is the most likely exposure route assessed as part of this research.

Inhalation of asbestos fibres can also lead to other injuries to the lung parenchyma and to a number of changes in the pleura (Boutin et al. 1989; Churg 1986; Ehrlich et al. 1992; Jones et al. 1988). The most common injuries are lesions referred to as pleural plaques. These are generally oval areas of acellular collagen deposits, usually located on the posterior surfaces of the pleura. Diffuse thickening and fibrosis of the pleura may also occur, as may pleural effusions. The prevalence of pleural abnormalities (usually detected by x-ray examination) is often quite high (10–60%) in people employed in asbestos-related occupations for sub-chronic (Ehrlich et al. 1992) and chronic durations (Gibbs 1979; Viallat and Boutin 1980; Baker et al. 1985; Ohlson et al. 1985; McDonald et al. 1986; Amandus and Wheeler 1987; Anton-Culver et al. 1989; Bresnitz et al. 1993; Hsiao et al. 1993; Chapman et al. 2003; Paris et al. 2009). Pleural abnormalities are also common in household contacts and family members of occupationally exposed workers. It is presumed that exposure is the result of asbestos carried home on the work clothes and there is ample anecdotal evidence of this being the case (Anderson et al. 1976, 1979). Increased rates of pleural abnormalities are also reported in people living in areas where tremolite asbestos-containing whitewash materials have been used (Baris et al. 1988; Constantopoulos et al. 1985, 1987; Çöplü et al. 1996; Dumortier et al. 1998; Metintas et al. 2002; Sakellariou et al. 1996; Yazicioglu et al. 1980), and in people who live in regions with high asbestos levels in the soil (Boutin et al. 1989; Churg and DePaoli 1988; Luo et al. 1992; Rey et al. 1993). An elevated prevalence of pleural abnormalities (3.7%) was noted in long-time (70-year) residents of an area with elevated levels of asbestos in soil (Boutin et al. 1989). Cumulative exposure to asbestos in these residents was estimated to be 0.12f-yr/ml (mean). The prevalence of pleural abnormalities (specifically, pleural thickening) in members of the general population of the United States was found to be 2.3% in males and 0.2% in females, most of which is probably due to occupational exposure to asbestos (Rogan et al. 1987).

The health significance of asbestos-induced pleural abnormalities is not precisely defined; some researchers consider pleural plaques to be essentially benign (Jones et al. 1988; Ohlson et al. 1985), whereas others have noted isolated pleural plaques to be associated with decreased ventilatory capacity (Bourbeau et al. 1990). In addition, some investigators (Edelman 1988; Hillerdal 1994; Hillerdal and Henderson 1997; Nurminen and Tossavainen 1994) have suggested that pleural plaques are predictors of increased risk for lung cancer, whereas another analysis (Weiss 1993) has suggested that they are not. Diffuse pleural thickening can lead to decreased ventilatory capacity, probably because of the restrictive effect of pleural fibrosis (Britton 1982; McGavin and Sheers 1984; Baker et al. 1985; Churg and Wiggs 1986; Jarvholm and Larsson 1988;

Jones et al. 1988; Miller et al. 1992; Rom and Travis 1992). In some cases, pulmonary impairment from pleural thickening can be very severe, even causing death (Miller et al. 1983).

2.3.5. Other routes of exposure

The risk of contracting disease from the ingestion (swallowing) asbestos fibres is not known, but many researchers feel that there is a link between ingestion and cancers of the digestive system. Also, when asbestos fibres are inhaled many are trapped in the nasal passages and some of these are cleared by being moved to the throat and then swallowed (ingested). Therefore, ingestion of asbestos fibres is also a function of the inhalation rates. The risk of contracting an ARD, in particular, cancer from ingestion of asbestos fibres is considered much lower than the probability of a disease contracted through inhalation. However, asbestos contaminated water can lead to inhalation exposure by depositing fibres on laundry or through evaporation of contaminated runoff. This research does not consider ingestion to be the primary point of exposure for the populations in the Study Area however it does warrant further consideration. Water significantly contaminated with asbestos as a result of asbestos-cement piping has been documented to increase airborne concentrations (Webber et al. 1988). Felix (1997) identified asbestos exposures related to washing of laundry with asbestos contaminated water in the villages of Ga-Mafefe.

Routes of exposure must also be considered in the assessment of the long-term exposures that are possible to the residents within the Study Area. Inhalation of asbestos fibres is the most prevalent route of exposure for residents within the Study Area. The conditions that can lead to inhalation along with the anticipated dose and period of exposure are of particular concern to this research. Rates of exposure expressed as fibres per millilitre (f/ml) have been determined for a number of occupational and environmental settings. Calculating these rates of exposure over a lifetime can lead to estimates of disease burdens within the exposed populations.

2.4. Cumulative exposure studies

EPA (1986b) estimated that continuous lifetime exposure to air containing 0.0001 f/ml of asbestos would result in approximately two cases of lung cancer per 100,000 smokers, a factor of 10 higher than that estimated for non-smokers (0.2 per 100,000). EPA (1986b) excluded available data for asbestos miners and millers from the analysis, based on the judgment that fibre characteristics of "preprocessed" asbestos in these environments would be different from those of "processed" asbestos fibres in the general environment (McDonald et al. 1980; Nicholson et al. 1979; Rubino et al. 1979). For smokers, cumulative exposures of 0.000035, 0.00035, 0.0035, and 0.035f-yr/ml represent excess lung cancer risks of one in 10^7, 10^6, 10^5, and 10^4 respectively. For non-smokers, cumulative exposures are increased by one order of magnitude in order to equal the same excess lung cancer risks. While these values have been considered to be the best available for assessing risk from environmental exposures to airborne asbestos, the range of uncertainty is probably a factor of 2.5–10 (EPA 1986b).

An alternative statistical analysis of studies relating occupational cumulative exposure to asbestos and lung cancer mortality arrived at lung cancer potency estimates that were 4 to 24 fold lower than the EPA model potency estimate (Lash et al. 1997). Hodgson and Darnton (2000) noted that exclusion of the chrysotile asbestos miner and miller data in the EPA analysis led to a higher estimate of potency (i.e., slope of the exposure-response relationship) than would have been obtained if the data were included, and suggested that a lower potency estimate would be more appropriate for populations exposed to non-textile chrysotile such as that used in buildings. Camus et al. (1998) reported that the EPA model predicted a relative risk for death from lung cancer in a group of non-occupationally exposed women who lived in two regions of Quebec with chrysotile mines that was at least 10-fold higher than the observed upper range for excess lung cancer deaths for this group. No statistically significant lung cancer excess was observed in this group of women. The standard mortality ratio (SMR) was 0.99 (95% CI 0.78–1.25), based on 71 observed lung cancer cases among 2 242 deaths from all causes (Camus et al. 1998). In defence of the EPA model predictions Landrigan (1998) noted that "the strong possibility exists that the Camus calculations underestimate the risk of asbestos exposure", due to: "1) the average fibre diameter in the Quebec mining townships is probably larger than average diameter encountered in industrial operations in the United States because asbestos in the Quebec townships had not been subjected to the extensive machining that asbestos found in U.S. textile factories typically undergoes; and 2) prevalence of cigarette smoking is much lower among women in rural Quebec than among blue-collar workers in the American south." (WHO 2006).

2.4.1. Fibre attributes

Considerable research has been conducted on fibre attributes as a function of increased disease risk. This issue is relevant to this research in that fibres found in the vicinity of former mines, as unprocessed waste tailings may be different than those found in more traditional occupational settings where the fibres have been milled and are being processed into finished products (such as textiles or cement materials). In addition, the exposed population of the environment is much more heterogeneous than the typical occupational cohorts that have traditionally been studied and therefore represent a different risk scenario to be considered, in particular, in setting appropriate risk tolerances as a part of public policy. For that reason, this research has considered a discussion of the current thinking on the biological influences of fibre size, shape, mineralology and exposed population characteristics. The following is only a brief review of the growing body of literature surrounding this topic.

Although findings confirm that all asbestos types can cause all three major ARDs there are numerous studies that suggest that amphibole asbestos (asbestiform actinolite, anthophylite, tremolite, amosite, and crocidolite) may be more potent than chrysotile (Weill et al. 1979; Henderson and Enterline 1979; Berry and Newhouse 1983; Churg 1986; Hughes et al. 1987; Churg and Wright 1989; McDonald et al. 1989, 1997; Newhouse and Sullivan 1989; Rogers et al. 1991; Sluis-Cremer et al. 1992; Jones et al. 1996; Rödelsperger et al. 1999; Hodgson and Darnton 2000; Wilson et al. 2008). A case-control study of a group of workers in a friction materials plant that used mainly chrysotile, but also used crocidolite on two occasions found that the workers dying from mesothelioma (11 cases) were 8 times more likely to have been exposed to crocidolite than workers dying from other causes (Berry and Newhouse 1983). In case-control analyses of fibre concentrations in autopsied lungs of mesothelioma subjects and subjects who died of other causes, relative risk for mesothelioma was significantly related to increasing concentrations of amphibole fibres longer than 5 μm (Rödelsperger et al. 1999), 8 μm (McDonald et al. 1989), or 10 μm (Rogers et al. 1991); significant relationships with increasing concentrations of chrysotile fibres were less apparent in these studies. In another approach, the chrysotile and amphibole content of lungs from persons dying from mesothelioma was examined and it was found that mesotheliomas occurred in amphibole workers with much lower fibre burdens than those observed for chrysotile workers. The authors concluded that amphiboles were two orders of magnitude more potent for inducing mesothelioma than chrysotile (Churg and Wright 1989). This has led to the hypothesis that many cases of mesothelioma in chrysotile-exposed workers are actually due to the presence of amphibole contamination (Churg 1986; McDonald et al. 1989). However, it is difficult to draw strong inferences regarding the relative potency of different mineral types from lung burden data, because amphiboles are more stable in lung tissue than chrysotile. Based on an analysis of the ratio of excess deaths from mesothelioma to excess deaths from lung cancer in a number of studies, EPA concluded that crocidolite could be 2–4 times more potent for mesothelioma than chrysotile, but that this difference was generally overshadowed by differences in fibre size distribution and differences between cohorts (USEPA 1986a). In a more recent analysis of exposure-response relationships for mesothelioma mortality in studies of 17 asbestos-exposed occupational cohorts, Hodgson and Darnton (2000) concluded that relative potencies ("exposure specific risk of mesothelioma") are in a ratio of 1:100:500 for chrysotile, amosite, and crocidolite, respectively (Hodgson and Darnton 2000). More recent analysis by the U.S. EPA (2003) has suggested that amphibole asbestos fibres may be up to 1 000 times as productive at inducing mesotheliomas as chrysotile alone (USEPA 2003).

2.4.2. Fibre size and shape

Asbestos is most dangerous as an inhaled dust. Fibres tend to travel parallel with the direction of airflow and therefore, respirability is primarily a function of the diameter of the fibre and not the length (Berman and Crump 1999). Those fibres with the highest propensity to reach the lower lung fall between 0.02 to 2.0 µm in diameter which, "theoretically represents the upper limit to the size of asbestos that is respirable" (Berman and Crump, 1999; pg 5-6). The hypothesis that dimensions and biopersistence are the primary agents in cancer induction with long, thin fibres being the most toxic is referred to as the *Stanton Hypothesis* (Stanton et al. 1981). Stanton reported a positive correlation between fibre length and carcinomas from animal implantation studies. Other reports based on fibre length show a role by short (<10 µm), thin (0.7 µm true diameter) fibres having the greatest efficiency at reaching the distal portions of the lung (Berman and Crump 1999, pp 5-8). Analysis by Dodson et al. (2003) and Suzuki et al. (2004) supports the assertion that all fibre lengths induce pathological responses. Asbestos fibres longer than 200 µm long and >3 µm in diameter are effectively eliminated by the upper naso-pharyngeal portion of the respiratory tract and do not enter the distal lobes of the lungs. These factors may change for childhood exposure (as described later in this Chapter). Of those fibres that enter the lower lung, a small portion exit through exhalation, those that remain impact on the terminal bronchioles and alveoli and penetrate due to the wetness of the lung surface. Fibres shorter than 5 µm are typically cleared through macrophage activity and pass through the body. Fibres longer than 5 µm become trapped causing scar tissue to develop as a result of inflammatory compounds. Some evidence points to a fibrotic role of short fibres (<5 µm) possibly due to their comparative larger surface area or the greater number of short fibres compared to long fibres per unit quantity of asbestos (Case et al. 1994). Others have argued that studies that determined asbestosis to be primarily related to longer fibres were based on faulty counting rules or practical detection limits (Berman and Crump 1999) wherein short fibres were either not counted or undercounted due to technical limitations.

Asbestos may be found in the environment in a variety of forms. These include individual fibrils, fibre bundles (groups of individual fibrils bound together), and cleavage fragments (naturally occurring or the result of milling); sections of the host rock broken into smaller pieces. Fibre bundles and cleavage fragments both maintain the potential to release fibres into the environment from mechanical abrasion and natural erosion from wind and water. Host rocks are also prevalent in the former mining areas, many still containing fibre seams which are also subject to abrasion from natural and/or human forces releasing fibres into the environment. However, the majority of the host rocks that are visible and hence may potentially release fibres into the air are the result of mining activities. They are generally part of overburden stockpiles, tailings dumps or near reclaimed areas.

There is a wide range of fibre sizes available in the soil and their tendency to become airborne from disturbance by various activities is poorly understood (US EPA 2004; Lubenthal 2009). Recent studies show that soil contaminated with tremolite asbestos levels as low as 0.08% is found to generate airborne exposures exceeding the U.S. occupational exposure limit of 0.1f/cc (Miller pers comm., 20 November 2003). According to the California Department of Toxic Substances Control, low levels of asbestos in soil can yield significant air emissions as a result of soil-agitating activities (Collier 2003). This position is corroborated by the Agency for Toxic Substances and Disease Registry (ATSDR), wherein it describes using a 1% level[13] as not a health-based standard (ATSDR 2003). According to other USEPA correspondence, clean-up thresholds should be established based on "background" levels, which may vary from rural to urban areas (Toland 2004 pers. Comm.). This study seeks to clarify where remediation of contaminated soil and building materials is warranted based on its likelihood of causing airborne concentrations above a *reasonable* standard. The assessment procedures outlined in Chapter 7 will be used to determine when remediation is appropriate and to what extent.

2.5. Occupational versus environmental exposure regulations

Most industrialized nations have regulated exposure levels to asbestos in the workplace. The current occupational exposure limit (OEL) in South Africa is 0.2 fibres per millilitre (f/ml) of air averaged over a 4 hour period. At that level of exposure, assuming an individual breathes 500 ml of air per breath, 15 breaths per minute, an individual will inhale 360 000 fibres over a 4 hour work period. There is no environmental exposure limit in the current South African legislation. It should be noted that the occupational limits established for asbestos exposure are related to a variety of technical issues. These include the industry capacity to reduce

[13] The U.S, classifies material as Asbestos Containing Material (ACM) if it contains greater than 1% by volume asbestos as determined by polarized light microscopy or transmission electron microscopy.

airborne concentrations through the use of appropriate technology, the analytical capacity of commonly used measuring devices, and the establishment of an "acceptable" level of disease burden within a society. The use of an "acceptable" level of disease burden is based on the fact that there is no safe level of exposure for asbestos, however; from a societal point of view a certain amount of disease risk is tolerable and acceptable particularly within an occupational setting. This is predicated upon several underlying factors including, industry compliance with the regulated levels, worker knowledge and acceptance of the assumed risk, and the accuracy of the risk models used to develop and estimate the disease burden related to various exposures. All of these factors have varying levels of impact to the final disease burden placed on society. In many cases, acceptable risk equates to an increase in lifetime mortality of from one within 100,000 to one within 1,000,000 of exposed population (California Environmental Protection Agency no date; Weis 2001). The relevant risk models are also based on a period of occupational exposure that typically equates to an average eight hour work-day, five days per week, 50 weeks per year over a 40 year work history.

Environmental exposure is not as strictly controlled in most countries as occupational exposure. This is the result of the common understanding (supported by a variety of studies) that environmental exposures are much lower (usually at least one order of magnitude) than occupational settings. The WHO, ATSDR, US EPA and others have all reported outdoor exposure levels at least one order of magnitude lower than indoor levels (see Chapter 6 for a more thorough discussion of environmental exposure levels). Given the relatively lower ambient levels of environmental exposure, the technical difficulties in further reductions in ambient concentrations and the notion of "acceptance" of certain degree of risks, very few countries have enacted laws that attempt to regulate ambient concentrations of asbestos fibres in the environment. This study has only identified proposed legislation in France that sets the standard at 0.025f/ml, though other recommended levels do exist. Table 2.3 presents the results of a literature search for appropriate ambient air standards and their sources of information.

Despite the numerous technical debates regarding fibre toxicity, risks and methods of measurement, there is an overwhelming agreement in the field of environmental health that all new uses of asbestos should be banned (LaDou et al. 2001). Due to the increased rates of ARD being experienced globally a number of countries have sought to ban or significantly curtail its continued use. This has largely been helped by the availability of suitable alternatives that have been demonstrated to provide similar properties to asbestos fibres.

Table 2.3: Selective recommended/regulated background limits for asbestos in the air

COUNTRY	AMBIENT/ENVIRONMENTAL EXPOSURE LIMITS	REFERENCE
South Africa	None	Air Quality Management Act, Act No 39 of 2004 and the Atmospheric Pollution Prevention Act, Act No 45 of 1965.
United States	None; Prevailing location specific ambient background levels are used for determining remediation standards	CERCLA*
Canada (Ontario)	0.01 f/cc (clearance standard for occupation of buildings)	Ontario Ministry of Labour Regulation 278/05 (2005)
France	0.005 f/ml	French Institute for Public Health Surveillance 2009
European Union	2.0 f/ml	EU industrial discharge limit to the environment / Dir. 87/217 (1987)
Israel	0.0014 f/ml	Ministry of the Environment

*U.S. Comprehensive Environmental Restoration, Compensation and Liability Act / NA = Not available

2.6. International bans on asbestos use

The continued commercial use of asbestos (including chrysotile) has been banned either entirely or for all uses for which an alternative material exists in over forty countries including all member states of the European Union and in South Africa (WHO 2006). A global ban on commercial use of asbestos has been urged by such organizations as the Building and Wood Workers Federation (IFBWW), the International Metalworker's Federation, the International Trade Union Confederation, the government of France, and the distinguished scientific group Collegium Ramazzini (World Bank 2009). Several relevant events with international impact coincided with initial bans on asbestos. These included:

- International Agency for Research on Cancer (IARC), acknowledging the carcinogenicity of asbestos in 1973 and then classifying asbestos as a human carcinogen in 1977 (IARC 1987); and,
- International Labour Organisation (ILO) adding lung cancer and mesothelioma caused by asbestos to its list of occupational diseases in 1980 and adopted the Asbestos Convention in 1986 (ILO 1986).

It was also around this period that the landmark studies by Selikoff and colleagues (Selikoff et al. 1972; Selikoff and Lee 1978; Nicholson et al. 1979) gained wide recognition. The adoption of bans by Northern European countries in the 1980s set a precedent for other countries, but the particular restrictions imposed by a ban vary by country, and the rates at which the absolute zero use levels were reached also vary. Collectively, countries adopting bans reduced use about twice as fast as those with lesser interventions (Nishikawa et al. 2008). However, despite the fact that many countries have banned the commercial use of asbestos, and many international organizations have supported bans and confirmed its ability to cause cancer, there is a recognised shift of asbestos export to industrializing countries, in particular, those in southern and Southeast Asia (Kazan-Allen 2005; LaDou 2001; Takahashi and Karjalainen 2003). Moreover, if the ecological relationship between use and disease holds true for the future, corresponding risks should be anticipated in these countries (Nishikawa et al. 2008; Joshi and Gupta 2005).

2.7. Assessment of environmental asbestos exposure

The assessment of asbestos contaminated communities represents a complex and unique set of circumstances and challenges. A literature review has revealed very little in the way of published documents (academic or government reports) on the topic of environmental contamination in South Africa. Sluis-Cremer (1965), Felix (1997), McCulloch (2002), Braun et al. (2003), Donohue (2007), REDCO (2007), Menjties et al. (2008), van der Walt and de Klerk (2009) and others do raise the issue but little is presented as hard evidence in the way of sampling to support their suspicions. Considerable research into environmental asbestos contamination is being conducted within communities adjacent to asbestos mines in Canada and Vermont in the United States. The discovery of environmental asbestos contamination in the town of Libby, Montana (resulting from the vermiculite mine and mill), is an example of environmental asbestos contamination occurring from the mining and milling of a separate ore (in this case vermiculite) that was contaminated with fibrous tremolite asbestos (ATSDR 2003). In circumstances reminiscent of South Africa, certain corporate officials are alleged to have known of the contamination occurring as part of the vermiculite mining and milling process but this information was never divulged to the workers or the community (Peacock 2003). Tailings from an asbestos mine in Lowell, Vermont (USA) have contaminated the adjacent property and raised concerns about potential health effects in the community. Within the Québec Province of Canada, the Institute National De Santé has compiled an extensive review of environmental asbestos monitoring (airborne concentrations) and disease in the towns surrounding the existing chrysotile asbestos mines (Institute National De Santé Publique Du Quebec 2004).

Much of the literature reviewed as part of this research focuses on specific issues related to environmental exposures, as opposed to occupational exposures which have been well defined in many industries over a period of decades. It is only more recently that environmental exposures (often including household or domestic exposures) have been investigated more fully. The issues that separate environmental from occupational exposures are many and varied with considerable overlap. The key factors that must be considered when assessing environmental exposures and risk are reviewed below. Chapters three through five describe how these factors were incorporated into the methodology for this research.

2.7.1. PCM versus TEM and risk assessment models

The early occupational exposure models for asbestos were largely based on technology that is now out-dated and possibly not representative of the actual fibre burdens encountered in the occupational environment. Measurements, and risk assessments were based largely on measurements using phase contrast microscopy (PCM) (ASTDR 2001; Perry 2004). Transmission or scanning electron microscopy is now considered the standard for fibre analysis and counting. Chapter three discusses the relative strengths and weaknesses of these technologies and methods and the resulting impact they have on predictions of environmental exposure levels and corresponding disease risk.

2.7.2. Mineralogical and physiological characteristics of processed versus naturally occurring asbestos

The mineralogical classification of asbestos encountered in the workplace may vary substantially from the types encountered in the environment. This is due to the fact that chrysotile has historically represented 90 percent of the worldwide consumption of asbestos and that even where amphibole asbestos is encountered in the workplace it is much less common (with the exception of specific uses or applications). Therefore using industry averaged, or population-based risk assessments (such as those based on epidemiological studies), may substantially underestimate the true risks from environmental exposures to asbestos, in particular within amphibole asbestos producing regions of the world such as South Africa.

The physiological properties of asbestos fibres in the environment may also be substantially different than those encountered in the workplace. Fibres that have been sorted, screened and milled may have dramatically different properties (such as length and width characteristics, surface area, etc) than unprocessed fibres encountered in the environment. To the extent that these differences in the size and shape of fibres encountered impacts upon their exposure rates and resulting risks has not been adequately demonstrated (Berman and Crump 2003).

2.7.3. Exposure scenarios and lifetime cumulative exposure models including age of first exposure

There is a growing body of literature that deals primarily with environmental exposures related to either domestic sources, area industrial sources (including mining) or naturally occurring asbestos. Pleural abnormalities have been documented as being common in household contacts and family members of asbestos workers and in people living in areas where tremolite asbestos-containing whitewash materials have been used (Anderson et al. 1976, 1979). Factories that use asbestos fibres (in particular, insulation and concrete) have been documented by Chang et al. (1999), and Trinh et al. (2004) to generate airborne concentrations of asbestos fibres. Fibres are emitted as fugitive emissions into the environment and carried downwind where they settle on surfaces and within homes and businesses. Musti et al. (2006) confirmed a link between malignant mesothelioma and environmental exposure from an asbestos factory. Demolition of buildings with asbestos containing building materials have also been documented to contribute to airborne concentrations of asbestos (Terazono 2004). Cutting of asbestos pipe and cement panels has also been shown to lead to high levels of asbestos dust (Castleman 2003; Kumagai and Nakachi 1993). Certain industries, such as asbestos cement plants, asbestos mills and textile plants are more likely to generate dust than others. The degree of environmental contamination identified within any particular setting can be a function of industrial controls, regulatory constraints, governmental inspections and corporate environmental standards.

A second key point concerning environmental exposures to ambient fibre concentrations is the age of first exposure and the duration of exposure. It has been well established (in South Africa and elsewhere), that environmental exposures do lead to asbestos related cancer, including mesothelioma and that a number of reported cases appear in people who were mostly likely exposed as children (due to the latency period) and for relatively short periods of time. Numerous cases in South Africa indicate a significant number of ARD in patients presenting with disease in their 30's and 40's. This is relatively rare in the literature for occupational exposures, but not uncommon for environmental exposures. As with many other asbestos related medical concerns, there is a paucity of data with respect to the actual ages of ARD victims. In the case of Libby, Montana, ARD is pronounced in younger patients. Of the 1 957 cases reviewed by the Libby Center for Asbestos Related Diseases (CARD) to date, 3.3 percent presented in their 30's and 9.7 percent presented in their 40's for a combined rate of 11 percent (Whitehouse 2008). Given the typical latency period for ARD this points to an almost certain early childhood exposure in most of these individuals. With predominately amphibole asbestos (such as Libby and most of the Study Area), "it appears that once a dose of asbestos sufficient to initiate the disease has been retained, it is inexorably progressive" (Sluis-Cremer and Hnizdo 1989 p 852). Due to the lack of epidemiological investigations for the environmentally exposes population of the Study Area this research chose to apply standard human health risk assessment methodologies in an effort to estimate the total disease burden. Key considerations of human health risk assessments and how these were dealt with in this research are described below.

2.8. Discussion of human health risk assessments

There are numerous definitions of human health risk assessment (HHRA), but most typically include, "the use of the factual base to define the health effects of exposure of individuals or populations to hazardous materials and situations" (USNRC 1983, p. 3). It is also referred to as a tool for identifying and quantifying the risks of chemicals and other events of adverse health effects, usually cancer. Paustenbach (1990) stated that risk assessment can be used to predict the likelihood of certain unwanted events such as, industrial explosions, workplace injuries, failures of machine parts, natural catastrophes, injury or death from an array of activities, diseases, or natural causes. Risk assessment is a process that describes and estimates risks and risk management is the process by which the risk is reduced (USEPA 1990). The conceptual model of risk assessment and risk management proposed by U.S. National Research Council (NRC) recognises scientific uncertainty in risk assessment and the role of science policy in addressing that uncertainty. It presents risk assessment as an objective scientific activity, distinct from risk management in its exclusion of social, political and institutional values (Brown and Goble 2002). The NRC model, though posed only for risks from chemicals, is widely accepted and it has been the basis for structuring much of the regulatory activity at the Environmental Protection Agency (Brown and Goble 2002).

The goal of risk assessment is to characterize a specific risk so that decision makers can conclude whether the potential hazard is sufficiently great that it merits active management or regulation, otherwise termed, "risk management." (Paustenbach 1990). In a risk assessment, the extent to which a group has been or may be exposed to a certain adverse condition (generally exposure to a harmful substance), and the extent of exposure is then considered in relation to the type and degree of hazard posed by the chemical, thereby permitting an estimate as to the present or potential health risk to the group. "Through the performance of risk assessments, researchers seek to understand the fundamental processes that underlie human health problems that are caused by pollutants in the environment. Risk assessments address questions of exposure and the adverse outcomes associated with exposure" (USEPA 2007).

Human health risk assessment uses toxicology data collected from animal studies and human epidemiology, combined with information about the degree of exposure, to quantitatively predict the likelihood that a particular adverse response will be seen in a specific human population (Paustenbach 1990). The assessment of toxicology data to predict health risks has been used by governmental agencies for many decades and over time has become more refined and quantitative (Paustenbach 1990). Since 1980, many environmental regulations and some occupational health standards have, at least in part, been based on the results of low-dose extrapolation models and exposure assessments. Risk assessment methodologies have been used to set standards for pesticide residues, food additives, pharmaceutical agents, drinking water, soil and air pollution, as well as exposure limits for contaminants found in indoor air, consumer products and hazardous waste clean-ups (Paustenbach 1990 and Lash 1997).

Human health risk assessment includes such factors as site characteristics, the toxicity of substances present in the environment, potential receptors, exposure pathways and it should discuss any uncertainty with the assumptions that are used (USEPA 2003). It typically involves four steps:

Step 1: Hazard Identification

Step 2: Dose-Response Relationship

Step 3: Exposure Assessment

Step 4: Risk Characterization (with risk characterization being the transitional step to risk management).

The following discussion of the four steps of risk assessment was excerpted and modified from "Principles of Risk Assessment: A Nontechnical Review" (ITRC 2007).

Hazard identification involves gathering and evaluating data on the types of health injury or disease that may be produced by a chemical and on the conditions of exposure under which injury or disease is produced. It may also involve characterization of the behaviour of a chemical within the body and the interactions it undergoes with organs, cells, or even parts of cells. Data of the latter types may be of value in answering the ultimate question of whether the forms of toxicity known to be produced by a substance in one population group or in experimental settings are also likely to be produced in humans. Hazard identification is not risk assessment; we are simply determining whether it is scientifically correct to infer that toxic effects observed in one setting will occur in other settings (e.g., whether substances found to be carcinogenic or teratogenic in experimental animals are likely to have the same results in humans).

With respect to asbestos, hazard identification is largely complete, subject to the current scientific debate over differences in toxicity between the amphiboles and chrysotile and low-level exposure thresholds. The hazard identification step for environmental exposure to asbestos is primarily discussed in terms of its carcinogenic effect and the induction of lung cancer and mesothelioma. For this research, the carcinogenic effect of all types of asbestos are considered irrefutable, however, it does recognise the growing body of consensus reviews that implicate the amphibole forms of asbestos as considerably more carcinogenic than serpentine (Perry 2004; Berman and Crump 1999; Lemen 2004). This is not to imply that chrysotile is or should be considered safe. The arguments stem from the toxicity of chrysotile, both in its raw form and as a processed material, which is frequently, but not always, contaminated with varying levels of amphibole asbestos (primarily anthophyllite and tremolite). Therefore, the extent to which the observed disease can be attributed to the amphibole contaminants in chrysotile and not the chrysotile itself is still a much contested issue (Stayner et al., 1996, 1997). Regardless, as applied to the induction of lung cancer, mesothelioma, and asbestosis, chrysotile asbestos satisfies all nine Hill Causation Model criteria (Lemen 2004). Suzuki et al. (2004) identified short, thin chrysotile fibres as being assumed to be carcinogenic. Yet no association of mesothelioma was identified within a cohort of South African chrysotile miners (Rees et al. 2001).

Dose-response assessment involves describing the quantitative relationship between the amount of exposure to a substance and the extent of toxic injury or disease. Dose is defined as concentration over time. For asbestos, a number of unit values are prescribed for exposure. Data are derived from animal studies or, less frequently, from studies in exposed human populations. There may be many different dose-response relationships for a substance if it produces different toxic effects under different conditions of exposure. The risks of a substance cannot be ascertained with any degree of confidence unless dose-response relations are quantified, even if the substance is known to be toxic.

With respect to asbestos dose-response curves have been established using a linear dose-response model for all three commercial varieties of asbestos (USEPA 1986; WHO 1986). A number of authors have suggested modifications to this model for application against amphibole versus serpentine (chrysotile) exposures due to the varying toxicity of the two classes of asbestos (Berman and Crump 1999; ATSDR 2001). There is still debate as to the specific dose-response applications for asbestos but based on a number of summary reviews the following consensus conclusions can be described.

- There is no safe level of exposure or no level of exposure for which disease risk is not increased. This is often described as the "one fibre theory" in that the risk of cancer or mesothelioma is increased by some level above zero with the inhalation of a single fibre. While this theory may be theoretically possible, the fact is that most humans contain a lung fibre burden of millions of asbestos fibres due to its natural occurrence and/or its ubiquitous presence in the environment from brake linings, building components or other man-made sources.

- The three primary ARD have been assigned dose-response relationships that conclude that very low exposures of amphiboles will lead to an increased risk of cancer but higher levels of exposure are thought to be required for the development of asbestosis.

Dose-response is not specifically addressed by this research. For purposes of maintaining consistency to established positions of the U.S. Environmental Protection Agency, the U.N. World Health Organisation (WHO) and the South African Department of Environmental Affairs (DEA), this research has accepted the premise of a linear dose-response curve for all three commercial varieties of asbestos with no lower threshold exposure level considered below which there is no increase in disease risk.

Exposure Assessment involves describing the nature and size of the population exposed to a substance and the magnitude and duration of their exposure. The evaluation could concern past or current exposures, or exposures anticipated in the future. Past asbestos exposures may be determined through the use of epidemiological surveys that take into account the latency period of ARD or they may be concurrent through the use of sampling equipment designed to estimate airborne concentrations. Exposure assessment for asbestos has undergone a number of changes over the past several decades, mostly brought about the increasing sensitivity of equipment, including the resolving power of electron microscopy and its ability to distinguish fibre types. Early measurements of atmospheric dust depended upon impingers which only measured airborne concentrations of dust, from which estimates of the fibre burden were then determined. This method was superseded by the use of air pumps that deposited fibres onto specially configured cellulose polycarbonate filters that were then analysed by optical microscopy with a much greater resolving power. The primary drawback to this method was the inability to distinguish between asbestos fibres and other fibre types, plus the resolving power was still not sufficient to characterize the very thin fibres that are still considered biologically active. However, this was a standard method used in the 1960s and 1970s when studies were completed to determine occupational exposures to asbestos. Transmission and scanning electron microscopy are the current methods employed that overcome most of these earlier constraints. Therefore, it is difficult to correlate studies done over varying time frames, using different sample collection and laboratory methods for analysis to establish one, generally accepted, level of exposure. Furthermore, no accurate correlation exists between PCM and TEM/SEM data that allows a straight-forward conversion.

Epidemiologic studies may identify a cause when people who have a given type of cancer are consistently found to have a history of unusually high exposure to a particular agent. Mesothelioma fits into this category as the vast majority of cases show a historic exposure to one or more forms of asbestos. Alternatively, a link can be declared when a weak relation between an agent and a form of cancer is consistently reported in a variety of circumstances and backed by persuasive biologic plausibility (Trichopoulos et al. 1996). Harris and Kahwa (2002) recognise that reliable epidemiological data are rarely available in developing countries. The lack of reporting of diseases and poor quality of health care delivery in South Africa reinforce the notion that quality data from which to develop epidemiological estimates is largely deficient (Braun et al. 2001). Therefore published studies must take into account the dearth of medical and exposure data, the irreconcilable nature of reported concentrations (due to varying sampling, laboratory and reporting methods) and the inherent weaknesses of risk assessment and epidemiology as a tool to accurately predict risks. Given these limitations, it is still proposed as the most accurate form of estimation for overall risk as a result of environmental exposure to asbestos and with the modifications described below is the preferred method for this research.

Risk characterization is typically the last step in human health risk assessment and generally involves the integration of the data and analysis of the first three components of the risk assessment process (hazard identification, dose-response and exposure assessment) to determine the likelihood that humans will experience any of the various forms of toxicity associated with a substance. (In cases where exposure data are not available, hypothetical risk can be characterized by the integration of hazard identification and dose-response evaluation data alone). A framework to define the significance of the risk is developed, and all of the assumptions, uncertainties, and scientific judgments of the preceding three steps are presented.

Risk assessment has been used extensively to establish and predict risks associated with asbestos exposure. A variety of human and animal studies have quantitatively linked asbestos exposure to a number of diseases, most prevalent being, asbestosis, lung cancer and mesothelioma. Human epidemiology has identified a quantitative dose/response relationship and risk coefficients for asbestos exposure, however the factors vary widely (Berman and Crump 1999). This is due in part to difficulties arising from the wide variety of occupational and environmental exposure scenarios, the poor correlations between various sampling and analytical protocols and uncertainties associated with the risk, in particular at low levels of exposure such as those commonly associated with the environment.

2.8.1. Criticisms of human health risk assessment

With such wide application of risk assessment, there is no shortage of criticism over its methods, results and applications. Criticisms of methods used to establish the risks from environmental asbestos exposure generally fall into two broad categories. The first is that the various methods typically employed significantly overestimate the actual degree of risk thus leading to over-regulation of industry and unrealistic expectations for benefits. The second criticism is that human health risk assessment, in many cases, under-estimate the actual risks and the very nature of assigning an "acceptable" level of increased risk is unethical. Additionally, the assignment of disproportionate risks over certain occupational or socio-economic groups for example brings up issues of environmental justice (Levy 2009).

Environmental asbestos exposures (measured as concentrations in ambient air) are typically several orders of magnitude below historic occupational exposure levels (Camus et al. 1998) and the application of a liner-dose response for the carcinogenic properties of asbestos have been questioned (Camus 1998; Berman and Crump 1999; Valic 2002). The issue is one of the appropriateness of extrapolating from industrial exposures to the much lower environmental exposures with increased uncertainty due to the variability in reporting methods and results. This is also compounded by the types of asbestos encountered in the environment versus occupational settings and the lack of apparent connections between expected and observed cancer rates attributable to environmental exposure (Camus 1998; Valic 2002; Berman and Crump 1999). Camus (1998) reported the U.S. EPA dose-response curve overestimated the risk of asbestos-induced lung cancer by a factor of 10. This "over-estimation" of risk may be the result of efforts to standardize the process of risk assessment that have introduced several levels of conservatism in an effort to be protective of public health (Paustenbach 1990). Despite it being one the most researched materials in the world, there is still enormous disagreement over specific outcomes of the risk assessment process for environmental exposure to asbestos.

The converse of these arguments is that risk assessment actually underestimates the cumulative risks to the general population in that it fails to take into account extraneous variables that may impact upon the results. Risk assessments developed from epidemiological studies have tended to look at otherwise healthy populations of workers or the general public. These do not always take into consideration those segments of the population that are potentially more susceptible to the negative impacts of exposure. For instance, infants and children may be more susceptible due to their less than fully developed immune systems, the elderly and chronically ill due to compromised immune systems. Certain ethnic groups may be more susceptible to specific diseases but for methodological reasons the issue of individual susceptibility is not addressed by risk assessments and there is no indication that asbestos (with the exception of smoking) is more causative than other agents. Lastly, occupational and environmental exposures are rarely confined to exposure to only one substance, yet most risk assessments make no attempt to estimate any contributory effects. The synergistic effect of exposure to multiple harmful substances may alter their health impacts in ways that are poorly understood. For example, the impact of cigarette smoking and asbestos exposure has long been well documented, yet whether this is a multiplicative or additive risk is still subject to debate (see ATSDR 2001 for a review of the literature surrounding this issue).

2.8.2. Background to risk-based assessments

Risk-based qualitative assessments are commonly used in building surveys for ACM. Numerous countries have adopted regulations or guidelines that deal with the risk of exposure to asbestos in buildings and how these risks are to be identified and managed. Australia has adopted the National Code of Practice for the Management and Control of Asbestos in Workplaces (NOHSC 2005). This practice requires, among other things, that the risks of exposure be assessed based on the location and condition of the ACM. The US EPA produced seven guidance documents for ACM in buildings including the Guidance for Controlling Asbestos-Containing Materials in Buildings (the Purple Book) in 1985 (USEPA 1985a) and the comprehensive legislation known as the Asbestos Hazard Emergency Response Act (AHERA) of 1986 (USEPA 1986a), then followed by the Asbestos School Hazard Abatement Reauthorization Act (ASHARA) of 1990 (USEPA 1990) which extended certain requirements of the law to all commercial and public buildings (but not single family or small residential buildings). The United Kingdom published regulations that also require the application of asbestos management, in particular to workers and self-employed individuals who may come into contact with asbestos during the performance of their job. These regulations do not apply to residences and to those workers whose exposure is considered to be of sporadic or low intensity. The determination is made through a risk assessment that considers such factors as: the condition of the material, its location (such as indoors or within a confined area), the disturbance frequency, its accessibility, the types of activities likely to occur, the number of occupants in the area and the quantity of material present (HSE 2006). South Africa does not address the existence of asbestos in buildings with the exception of demolition activities that may result in fibre releases (Demolition Regulations of 2006 – OHSA 2001 as amended). There are no regulations in South Africa that specifically deal with environmental contamination from asbestos. However, the over-riding legal threshold to be met is Chapter 2 (Bill of Rights) of the South African Constitution, Section 24a which states, "Everyone has the right to an environment that is not harmful to their health or well-being" (Constitution of the Republic of South Africa 1996 Section 24a).

It is clear from a review of the relevant literature and numerous public and industry guidance documents that the condition of the asbestos containing material is a primary consideration in the determination of risk. The issue of contamination from other media, such as soil is not adequately addressed in the literature and what guidance does exist can be contradictory. For example, the City of Cambridge, MA passed the "first in the nation asbestos protection ordinance" dealing with soil in 1999 which stated that soil found to contain less than 1 percent asbestos fibres (normalized area per EPA Region 1 Method) can be disturbed without any mitigatory measures to reduce dust or exposures (City of Cambridge Ordinance 1999). In 2000 a US EPA press release stated, "As a point of reference, EPA considers soil samples with one percent or less asbestos to be an acceptable level" (EPA Region 1 2000). Much of this confusion has stemmed from the US definition of asbestos containing materials as any material that contains greater than one percent asbestos by weight (EPA NESHAP 40 CFR Part 61 Subpart M date). These standards were based more on the capability of the analytical methods used to determine the presence of asbestos in bulk materials than actual risk assessment procedures and were never considered a health-based standard (ATSDR 2003). Recent studies show that soil tremolite asbestos levels as low as, 0.08 to 0.01 percent are found to generate airborne exposures exceeding the U.S. occupational exposure limit of 0.1 f/cc (Davies 1996; Miller 2003). According to the US EPA clean-up thresholds should be established based on "background" levels, which may vary from rural to urban areas (Toland 2004 personal communication). More recent attention has been focused on the issue of how to accurately analyse soil to determine its asbestos content and at what point does this level become a health risk (see discussion in Chapter 4 of this research for a review of various laboratory methods). At the most recent Johnson Conference (2008), no less than twenty presentations on the subject of soil contamination, detection and risks were provided and two of the nine sessions were dedicated to the topic.

Risk assessments for asbestos contaminated soil generally state that levels that approach 0.1 percent by weight (or by normalized area) are capable of producing levels of respirable fibres at or approaching occupational exposure limits. Davies et al. (1996) have shown that regardless of fibre type, significant airborne exposures can be expected from soils contaminated by less than one percent asbestos (even as low as 0.001%). These findings are confirmed by the results of activity-based sampling by the EPA and ATSDR at numerous other locations (see Chapter 6), and confirmed within the Study Area by findings of REDCO (2007) and this research. Within the U.S., states such as Colorado (2007), Pennsylvania (2000), and Massachusetts (2007) have either adopted or are in the process of adopting regulations to manage the occurrence of asbestos contaminated soils. Thus, semi-quantitative assessment of the distribution of the asbestos contaminated soil or waste and potential for asbestos fibres to become airborne remains the important aspect of exposure assessment (Colorado Department of Public Health 2007).

The government of Western Australia has adopted regulations for the management of asbestos contaminated sites (Government of Western Australia Department of Health 2009). Soils containing greater than 0.001 percent asbestos by weight are regulated and management guidelines are provided. These regulations recognise that there is no validated method in Australia (or most other countries) to reliably estimate the concentration of free asbestos fibres within the soil and the determination should then be based on the presence or absence of fibres. It also recognises the confounding issue of naturally occurring asbestos (NOA). This regulation relies upon the experience and expertise of the site investigator to employ a 'weight of evidence' approach to site characterization with the identification of trace levels of contamination considered significant (Government of Western Australia Department of Health 2009).

2.9. Determining an "Acceptable" level of risk

It is appropriate to determine a risk level that is acceptable to society in order to assess if risk reduction measures are necessary. Lash (1997), states that using comparative risk assessment provides a useful structure to managing the intersection of public and scientific values in order to implement good policies. However, the under-estimation of risk to environmental exposures to carcinogens in general, and asbestos in particular is still a concern (Perera 1996). This concern relates to the ability to accurately characterize exposure, the synergistic effects of exposure to multiple carcinogenic agents and the unequal response to exposure from certain segments of society (Covello 1991; Perera 1996). The most controversial provisions of current methods of quantitative risk assessment are the default assumptions for quantifying exposure and risk at very low levels, in the range generally considered acceptable by policymakers (that is, one estimated excess death attributable to the exposure per 100,000 down to 1,000,000 persons). The major default assumption is based on a single-hit theory as the basis for the linearized multistage model of carcinogenesis, which provides the rationale for the statistical approaches used to derive unit risk estimates from experimental dose-response data. Because policy decisions require estimation of dose beyond the range of feasibly obtainable experimental or human data, inference rules must be used to extrapolate to the range of concern. Since 1980 EPA has relied on the assumption that chemical carcinogens at small doses nevertheless increase the probability of cancer by some amount greater than zero, and that in the low-dose range, increments of dose are associated with proportional increases in risk (US EPA 1986b).

2.10. Conclusions

The world is currently experiencing an epidemic of asbestos related disease, in particular, mesothelioma. Globally, an estimated 124 million people yearly are occupationally exposed to asbestos and 89,000 die annually from asbestos related diseases (WHO 2006). There are no reliable estimates as to the number of individuals environmentally exposed to asbestos. The background behind this pandemic is related to three factors:

1. Asbestos production and consumption peaked in the mid-1970s but because of the latency period from time of exposure to onset of disease

(typically 20 to 40 years), we are now seeing what is expected to be the apex of the disease burden.

2. The ubiquitous nature of asbestos in over 3,000 commercial products, (prior to its banning in many countries), including substantial portions of our built environment, creates a public health issue for the entire world. Asbestos fibres, as minerals, are biologically inert, do not decay, nor do they break down into less harmful constituents. In fact, the inverse is true in that over time, asbestos containing material degrades releasing more and more fibres into the environment. As the life span of infrastructure and products containing asbestos expire the hazardous material will become ever more present.

3. Because of the continued mining, distribution and use of asbestos, namely chrysotile, the continuation of the public health concern will extend for many more decades.

According to the United Nations World Health Organization's (WHO) International Agency for Research on Cancer (IARC), and the International Programme on Chemical Safety (IPCS), the United States Environmental Protection Agency (US EPA), Occupational Safety and Health Administration (OSHA), the Centre for Disease Control (CDC), National Institute for Occupational Safety and Health (NIOSH), Department of Health and Human Services (DHHS), the Public Health Service (PHS), the Food and Drug Administration (FDA), the Agency for Toxic Substances and Disease Registry (ATSDR), the European Union (EU) and a host of other international scientific and medical bodies, all forms of asbestos are carcinogenic. Some of the central questions still subject to debate however, include: are all forms of asbestos equally toxic and if not, how do they differ in toxicity. Also what are the physical attributes of asbestos that contribute to its toxicity, for example, which fibre dimensions should be considered most biologically active with respect to toxicity and is there a lower threshold of exposure that could be considered safe. What is also important is for environmental exposures to be quantified and assessed. While this has been reported in specific locations it has not been assessed over a large geographic region where conditions and populations are sufficiently homogenous to consider cumulative lifetime environmental exposures.

CHAPTER 3

3. IDENTIFICATION OF COMMUNITIES POTENTIALLY AT RISK FROM ENVIRONMENTAL ASBESTOS EXPOSURE

Seems fluid fills up 24 hours after drained!! Difficult to breathe, sit, walk, etc. Feel weak and so useless! Please dear Lord, MERCY!!! (October 12, 1995) Life is very "meaningless" as I get weaker and ache so much. Please forgive me, but I do wish it were over to stop this useless suffering for us both! (October 16, 1995) Restless. Need two-hour pain pill. Nurse called and will check me. (October 28, 1995)[14]

3.1. Introduction

Chapters 1 and 2 identified the need for a systematic assessment of environmental contamination resulting from the former mining of asbestos in South Africa. Asbestos mining occurred in four provinces of South Africa (including the former autonomous homeland of Bophuthatswana). These Provinces comprise 682 thousand square kilometres, an area larger than the countries of Germany and Poland combined (South Africa Municipal Demarcation Board 2000). Within this area, there are an estimated 185 mines and 578 waste disposal sites according to the Department of Minerals and Energy (Venter 2004). However, anecdotal reports of environmental contamination as a result of improper disposal and/or use of asbestos waste question the accuracy of this estimate (Kisting 2000). There are also numerous communities and towns located in close proximity to the former asbestos mines and dumps with reported claims of significant environmental contamination (Braun et al. 2001; Kisting 2000). The actual extent of environmental contamination resulting from the former mining of asbestos and its improper use and disposal are a subject of significant uncertainty.

It is well established that environmental contamination from asbestos may occur as a result of a number of factors in addition to mining. Castleman (1996), McDonald (1985), Singh and Thouez (1985), and Huncharek (1986), among others, have noted that environmental contamination has resulted from the transport of asbestos

[14] Lee Joireman's diary entries. Died on November 2, 1995 of mesothelioma at age 57 after working for less than two years at a plant exfoliating Libby vermiculite when he was 21. Quoted with permission of the family. Also quoted in, An Air That Kills. Schneider, Andrew and David McCumber. 2004. The Berkley Publishing Group, pp. 174-175.

fibres from the mines along transport networks (rail and road), and at points of loading/offloading. In particular, South African ports that shipped asbestos overseas have been confirmed as containing residual asbestos contamination. The Port of Port Elizabeth for example maintains a storage yard where asbestos was offloaded from road and rail carriers and loaded onto ships. This portion of the Port was found to contain visible asbestos soil contamination twenty years after the last shipment went out and after the area had been "cleaned" of asbestos waste (P. Madikizela 2005 pers. comm. 15 June). Rail lines have been identified as containing asbestos contamination where bags of asbestos fibre have fallen off rail cars and continued to lie unremediated along the tracks (V. Matabane 2009 pers. comm. 8 August). There have also been reported incidents of rail siding contamination and some of these locations were investigated as part of this research. Much of the road contamination documented in the Northern Cape and other asbestos mining regions in South Africa is the result of material falling off of trucks carrying the bagged asbestos from the mills to various staging points (Viridius 2002; Braun et al. 2003). While there are likely isolated but potentially wide-spread locations of asbestos contamination from the transport of asbestos materials within South Africa, the transport network was not assessed by this research unless it fell within the other research parameters as outlined below.

A literature review has revealed very little in the way of published documents (academic or government reports) on the topic of environmental contamination in South Africa. Felix (1997), McCulloch (2002), Braun et al. (2003), Donohue (2007) and others do raise the issue but little is presented as hard evidence in the way of sampling to support their suspicions. Considerable research into environmental asbestos contamination is being conducted within communities adjacent to asbestos mines in Canada and the U.S. The discovery of environmental asbestos contamination in the now infamous town of Libby, Montana (resulting from the vermiculite mine and mill), is an example of environmental asbestos contamination occurring from the mining and milling of a separate ore (in this case vermiculite) that was contaminated with fibrous tremolite asbestos (ATSDR 2003).[15] In circumstances reminiscent of South Africa, certain corporate officials knew of the

[15] More information on the situation in Libby, Montana and the parallels to South Africa are presented in Chapter 7

contamination occurring as part of the vermiculite mining and milling process but this information was never divulged to the workers or the community (Peacock 2003). Within the Québec Province of Canada, the Institute National De Santé has compiled an extensive review of environmental asbestos monitoring (airborne concentrations) and disease in the towns surrounding the existing chrysotile asbestos mines (Institute National De Santé Publique Du Quebec 2004).

Many of the former asbestos mines in South Africa have already been or are scheduled to be rehabilitated by the South African Department of Minerals and Energy Affairs (DME). However, based on the examples cited above, what remains to be determined is the extent and severity of asbestos contamination that extends beyond the traditional mine footprint. Secondary environmental contamination within those areas that fall outside of the responsibility of the DME have been largely ignored in prior rehabilitation efforts. Due to the costs and logistics involved in remediation and the limited funding available it is necessary to assess the extent and risk of the secondary contamination so as to determine the true extent of the problem and then prioritize the efforts.

Asbestos risk is a function of exposure which is related to the capacity of asbestos fibres to become airborne (ATSDR 2003). This results from asbestos being entrained in the atmosphere as a result of actions that dislodge fibres from their source. The condition, concentration and setting (proximity to humans) and actions (natural or anthropogenic) acting upon the asbestos are key elements in determining the level of airborne exposure. It is therefore necessary to physically assess these conditions in the field in order to determine the potential for risk and thus the appropriate risk reduction strategies. Therefore, most environmental assessments of asbestos are conducted on a site by site basis in order to make a determination as to the criteria listed above and to make specific management decisions concerning the level of risk and any necessary remedial measures. Examples of strategies in making these determinations are provided in a number of governmental and institutional publications (ASTM 2004a; USEPAb 1985). These methods primarily deal with installed asbestos products and are not applicable to regional assessments of potential contamination. In fact, there are very few instances where large regional assessments of environmental asbestos contamination have been conducted. Mapping of environmental asbestos contamination has occurred in California (mapping of naturally occurring asbestos [NOA] in the vicinity of El Dorado Hills (USEPA 2005) and community wide sampling and mapping efforts have been undertaken in the area around Libby, Montana. Within South Africa the only large scale work to date has been the investigation of the Ga-Mafefe region by Felix (1997) and an investigation of the Prieska community (REDCO 2007). These works are addressed in more detail in Chapter 6.

In order to adequately characterize a given site or a building it is not uncommon to collect hundreds of samples per site or building depending upon the size and complexity of the area to be assessed. For instance, the USEPA AHERA regulations for schools require samples of suspected asbestos containing, friable, surfacing material be taken at a rate of three samples for up to 1,000 square feet (92.9 meters^2) of homogeneous[16] material (USEPA 40 CFR Part 763.86). The ASTM E2356 Standard for building surveys requires a minimum of three samples for any homogenous area regardless of friability and location (ASTM 2004a). A standard home survey may only require several samples (typically less than 10) to adequately identify the presence of asbestos while an industrial facility complex may require hundreds of samples to accurately assess the existence, condition and quantity of asbestos containing material (ACM). These methods are geared towards building surveys and are applicable to South Africa but they do not provide information on soil sampling methods or intensities.

Obviously, given the geographical extent of the former asbestos mining regions, the potential for large areas of contamination was likely and the ability to effectively and systematically survey these areas required an approach different than the traditional building assessment methods. Yet, the sampling intensity needed to be rigorous enough to adequately characterize the extent and severity of environmental contamination as a "screening level" study. The objectives of this Chapter are then as follows:

[16] AHERA defines a "homogenious area" as being uniform in color and texture. For larger areas, 5 samples are required (>1,000 square feet up to 5,000 square feet) up to 7 samples per homogenious area for greater than 5,000 square feet.

- Identification of those communities suspected to be high risk with respect to environmental contamination.

- Identification of those locations within each community that are representative of areas suspected for environmental contamination and of risk factors that may lead to public exposure.

3.2. Methods and materials

This section describes the process used to identify those communities suspected of having significant secondary environmental contamination. The first objective of this portion of the research was to define a systematic approach for determining those communities at risk and the second objective was to identify those locations within these communities where field level surveys should be conducted. A number of methodologies were evaluated to determine the most appropriate to accomplish these objectives. The approach is one of continuing refinement with the first level of assessment being characterized as a desk-top review augmented by knowledge of local community representatives.

3.2.1. Identification of communities suspected to be at risk for environmental contamination

The identification of asbestos in the environment, occurring over a large surface area is problematic due to scale and the ability to accurately identify the presence and condition of asbestos containing materials (either naturally occurring or commercialized). The use of published geologic maps (for example the South Africa Map of Geology) to aid in the identification of source mineral deposits is a valuable first step. An initial attempt to correlate asbestos bearing rock strata with mine sites and communities was undertaken using the Geologic Atlas of South Africa and 1:50 000 scale topographic maps produced by the Department of Maps and Surveys. Mine sites are identified on the topographic maps and these were found to be useful tools for planning of survey efforts. However, as the same mapping symbol is used for all mine types, it was not clear from the maps as to which mines were asbestos versus other types (such as manganese or iron ore) which are also prevalent in the region. In addition, it was known from previous research (McCulloch 2002; Felix 1997) that much of the mining occurred at local (potentially unmapped) outcrops and through digging/blasting of small adits (also referred to as "tributer mining"). Therefore, the use of the existing DME Rehabilitation Priority Index (RPI) database (Eko Rehab 2003), combined with the geologic formation and topographic overlays was considered to provide the most accurate data for an initial desk-top assessment. The DME RPI database had been compiled from field work completed over a period of fifteen years through the rehabilitation of ownerless and derelict mines.

Remote sensing of the region using aerial scanning technology (spectrometers) mounted on fixed wing aircraft was considered as a method to map the existence of asbestos in soils and possibly building materials. This method was used in California, USA to identify serpentine bodies of rock in the foothills of El Dorado County. Here, natural outcrops of serpentine and ultra-mafic rocks that contain asbestos are known to exist and hundreds of kilometres of roads have been surfaced with asbestos-containing gravels (Bowman and Yost 2004). While still considered "experimental" by the U.S. Geological Survey (USGS) and the National Aeronautics and Space Administration (NASA), according to the California Geologic and Hazards Mapping Program, a good correlation was achieved with the method compared to more traditional field sampling techniques of the same area (Higgins and Clinkenbeard 2006). Swaze et al. (2004) found the method to be useful but field-level sampling was still required to ascertain the actual existence and condition of asbestos contamination.

While this method appears to hold promise for conducing initial screening surveys of areas thought to contain substantial levels of surface contamination of asbestos, it was not chosen as a suitable method for this survey for the following reasons:

- The method has not been used in South Africa and the equipment is not readily available.
- The sensitivity of this method to detect asbestos at low concentrations has not been determined. Asbestos-bearing gravels identified in the California trial exhibited high levels of asbestos content but the ability to detect trace levels of asbestos was not determined.

- The condition of the material and the ability to make determinations as to the risk of exposure cannot be obtained from the remote sensing results and would still require site specific surveys by trained technicians.

Based on these factors, remote sensing was not used as a survey method in this research. It does however hold promise for surveying contaminated road surfaces, of which, there are likely hundreds of kilometres within the Northern Cape alone.

The first objective of this research was to develop a methodology to determine which communities are suspected for environmental asbestos contamination and thus should be subjected to a more refined survey in order to establish the true scope and severity of environmental contamination. The geographic coordinates of the existing known mine sites within South Africa were obtained from the DME RPI database. This database also included data on the type of asbestos mined, dumps and rehabilitation status. A series of GIS location analyses was performed using the Arc View Geographic Information System (GIS) software (version 8.1) to determine those villages at the greatest risk for potential exposures based on the following protocol developed for this study. The location of known source points (mines and mine dumps) was converted to a shape file and then overlain onto the base topographic data set (South Africa Directorate of Surveys and Mapping 1984) showing village locations, roads, water courses, topography, and other physical surface features. This data was generally viewed at a scale of 1:50 000. A series of 1 kilometre concentric circles, extending out to 5 kilometres was drawn from the point file provided for each identified source (mine site or dump).

The selection of a five kilometre threshold distance was based on a number of considerations. First, it has been demonstrated that airborne asbestos concentrations from source points diminish with distance due to dispersion and dilution (Pratt GC., 2001 as quoted by ATSDR 2003; van der Walt and de Klerk 2009). Though individual asbestos fibres may travel a considerable distance from their source point on wind currents, it was thought that airborne concentrations would decrease with distance at a rate of approximately two orders of magnitude from the initial source to a distance of five kilometres (Turner 1970). A maximum distance of five kilometres should then be sufficient to capture the majority of any depositional fallout from the original point sources (or even those point sources several hundred meters from the theoretical centre point). The Hazard Ranking System (HRS) utilized by the US EPA at the El Dorado Hills exposure assessment focused on occupied residences, schools and workplaces within four miles (6.7 km) of the sources of asbestos contamination (US EPA 2005). The issue of risk of asbestos disease (in particular mesothelioma) as a factor of distance from a source was further corroborated by Dodic-Fikfac and Franko (2006) who found that 90 percent of all cases of mesothelioma were within two kilometres of the alleged sources of asbestos pollution in Slovenia (multiple sources were surveyed). Musti et al. (2009) identified a significant odds ratio for mesothelioma within 500 metres from the centre point of asbestos cement factory. Magnani et al. (2000) determined an increased risk of mesothelioma due to environmental exposure could be identified within 5 kilometres of an asbestos mine or industry. Maule et al. (2007) found strong evidence of a link between mesothelioma rates and distance from sources of contamination with a 40 percent reduction in mesothelioma cases at a distance of 10 kilometres for the source point (factory). Pan et al. (2005) found a decrease in mesothelioma rates of 6.3% per 10 kilometres from sources of naturally occurring asbestos in California. Case and Sebastien (1987) found increased lung fibre burdens for environmental exposures within 40 kilometres of asbestos mines. Based on these studies it was not clear that any linear correlation could be drawn between distance from a source point and levels of disease. However, based on anecdotal information, it was also known that much of the asbestos used in local construction was obtained from the mine and dump sites and it was thought that at a certain threshold distance, the use of an alternative non-contaminated source (such as river sand) would be preferred. Based on these considerations and conversations with local representatives of the Study Area it was determined that a five kilometre distance would be sufficient in most cases but that it may need to be extended to account for locally specific conditions.

A drawback to this method is that the concentric circles were plotted from a single theoretical centre point location, (not necessarily the centre point of the mine site). In many cases the actual diggings, dumps and other potential sources of contamination are scattered over many hectares and it is difficult to determine a centre point. For consistency the centre point applied by the DME data set (Eko

Rehab 2003) was used. A second drawback to this method is that the five kilometre radius represents a total area of 6 667 square kilometres, too large to effectively assess the levels of asbestos contamination at the community scale. It was thus necessary to develop an appropriate fine-screening methodology.

In order to overcome these constraints it was necessary to develop criteria to narrow the scope of study to only those communities considered most at risk for environmental asbestos contamination. In order to do this, the number of villages, residences and land uses were ascertained for the area within the concentric circles. Predominant wind direction, as obtained from the South African Weather Service, (Kruger 2002), surface topography and slope, drainage courses, roads, paths and physical barriers (fences, walls, etc) were noted on 1:50 000 scale topographic maps representing all four former asbestos mining provinces.

The predominant wind patterns were sourced from the nearest weather stations for each region. This data was mapped and the resulting GIS maps provided the starting point for the prioritization of communities for field survey work. Table 3.1 and 3.2 list the weather stations used for each region and the quarterly dominant wind directions since 1952 are used (Kruger 2002).

Table 3.1: Wind data for the Northern Cape region

DOMINANT WIND DIRECTION BY QUARTER	UPINGTON STATION	KIMBERLEY STATION
January	Southwest	North
April	North	North
July	North	North to Northeast
October	Southwest	North

Table 3.2: Wind data for Limpopo and Mpumalanga regions

DOMINANT WIND DIRECTION BY QUARTER	PIETERSBURG (POLOKWANE) STATION	ERMELO STATION
January	Northeast	East
April	Northeast	East to Northwest
July	Northeast and South	Northwest
October	Northeast	East and North

A review of the relevant wind data yielded a high degree of variability in both seasonal direction as well as a significant variation of diurnal directions. For instance, all four stations indicate a 180 degree direction shift during the winter period. In addition, for weather stations in the interior (such as all four of these), high wind gusts are known to occur and are usually associated with thunderstorms. Whirlwinds are also known to occur in the interior (Kruger 2002). A subsequent analysis of van der Walt and de Klerk (2009) identified an exponential increase in fibre concentration at wind speeds approaching 8 m/sec^{-1} but these were found to occur at only 5-14% of the time (Prieska and Postmasburg respectively) within the Study Area. Fibre concentrations were predicted to be naught at distances approaching and greater than 10km from a source and at wind speeds below this rate (van der Walt and de Klerk 2009). Given the high variability in wind direction (both daily and seasonally) it was decided to discount this variable and concentrate on the surface conditions of the regions.

A series of 46 Preliminary Risk Assessment maps were generated for the Northern Cape and North West Province depicting the 79 known locations of asbestos mines and dumps as previously identified on the RPI database. A series of 27 Preliminary Risk Assessment maps of the 37 known locations of asbestos mines and dumps were prepared for the Limpopo and Mpumalanga Provinces. One map was prepared for a single site in Gauteng. Upon site inspection, the Gauteng site was found to not exist at the coordinates provided and no further information on this potential site was available. It was thus not considered further in this research.

The villages and communities falling within the 5 kilometre radius of the point sources were then ranked for their priority for community survey efforts as either: High, Moderate or Low. The ranking was based on the following rationale developed for this research:

High Priority: Villages and communities within 1-2 kilometres in any direction of at least one known source.

Moderate Priority: Villages and communities within 2 to 5 kilometres of at least one known source and that had an identified watercourse or road and/or track access linking the community to the source of asbestos within the 5 kilometre radius. Additional communities beyond the 5 kilometre buffer were added based on the results of meetings with local community representatives.

Low Priority: Villages further than 5 kilometres and where community representatives were not aware of any existing mine sites, dumps or environmental contamination.

It is important to note that this initial assessment was used to guide the selection of communities to be subjected to more detailed surveys but modifications were made to account for field conditions that differed from the desk-top analysis. Other additions or deletions were based on the prior knowledge of local participants.

3.2.2. Identification of locations within each community for more detailed assessment

The second objective of this Chapter was to describe the methodology used to identify those locations within each community where specific assessments were needed to adequately characterize the extent and severity of environmental asbestos contamination. The following is a review of the methodology used. The first task was to organize community representatives to ascertain their level of knowledge as to the existing conditions with respect to environmental asbestos contamination.

3.2.3. The inclusion of local indigenous knowledge

Michie (1999), Harmsworth (1998) and Jacobs et al. (2004) identify local indigenous knowledge as an important consideration in the planning of environmental mapping activities and this project proved no exception to those findings. A workshop was held with seven local representatives of the Asbestos Interests Group (AIG) in Kuruman and with one representative of the Prieska region. The representatives were primarily members of the local communities with experience in community engagement surrounding the issue of asbestos contamination and compensation claims. In other cases they were municipal or provincial level government representatives familiar with the issue. The community representatives reviewed the previously prepared Preliminary Risk Assessment maps to compare their knowledge of local conditions to that represented by the initial GIS analysis. This was assisted by the use of Rapid Rural Appraisal (RRA) maps previously generated by the Asbestos Interest Group (AIG) (see Figure 3.1)[17]. These maps were compared to the 1:50 000 scale Preliminary Risk Assessment maps and additional locations were added or deleted as deemed appropriate by the consensus of the participants. A total of eleven RRA maps for the Northern Cape were compared to the corresponding Preliminary Risk Assessment maps in order to determine specific locations for the community survey efforts in those locations.

RRA maps were not completed for Limpopo and Mpumalanga as the AIG was not active in that region. However, discussions were held within each community, typically with the village chief or elder to determine their knowledge of the environmental asbestos contamination within their area. These meetings were mostly informal and conducted in the local language by a facilitator (Stephen Kotoloane) working with the author.

[17] The process of Rapid Rural Appraisal (RRA) was carried out by researchers from Brown University, the University of Cape Town, and Peninsula Technikon and reported in, Asbestos-related disease in South Africa: Opportunities and challenges remaining since the 1998 Parliamentary Asbestos Summit (Braun et al. 2003) and by Jacobs et al. (2004). RRA is more commonly described as a systematic but semi-structured activity out in the field conducted by a multidisciplinary team that includes semi-structured interviews and direct observation (FAO 1989).

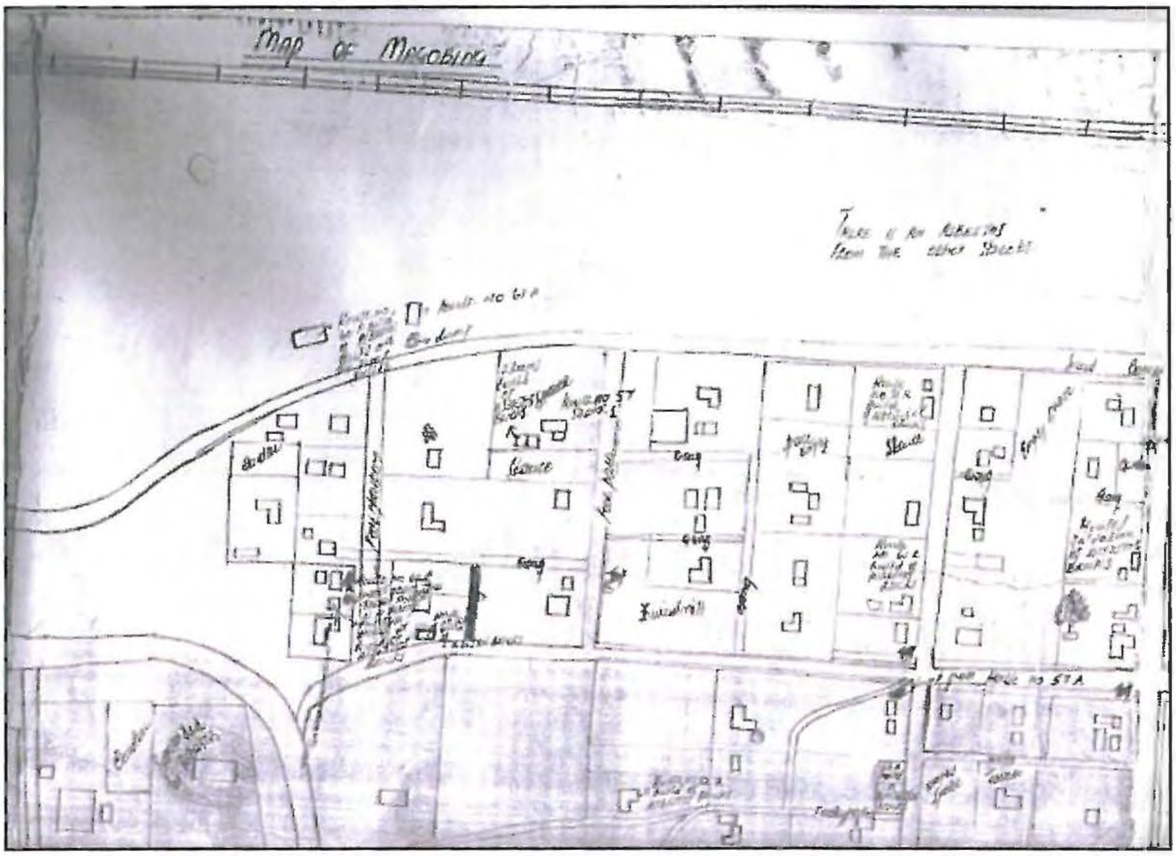


Figure 3.1: Example of Rapid Rural Appraisal (RRA) mapping of Magobing community based on research conducted by Braun (2003).

3.2.4. Identification of land uses within villages to be surveyed

The initial desk-top assessment also considered land use as an indicator of risk. As mentioned in the introduction to this chapter, risks from environmental asbestos is a function of exposure which can occur as a result of natural conditions (wind borne dust) as well as human-induced activities (physically disturbing asbestos containing materials such as soil or contaminated surfaces). Thus, land uses within the target communities were determined to be a proxy for the intensities of exposure that may be encountered in a non-occupational setting. A list of thirteen potential land uses were developed and provided to the field inspectors for inclusion in their field data forms. As there are no maps of land use or zoning within the Study Area, the determination of land use was made by the field inspector during their site assessment.

3.3. Results for the identification of those communities suspected to be high risk for environmental contamination

Figures 3.2 through 3.5 represent the initial mapping of the DME generated point locations and the corresponding five kilometre buffer shown at the provincial scale. These maps represent the coarsest level of assessment and were used to identify communities in proximity to the known locations of asbestos mines and dumps. One map for each of the four former asbestos mining provinces was generated.

The priority mapping was then discussed with the AIG representatives using the RRA techniques described above and a final selection of communities to be surveyed was completed. The RRA maps were reviewed with community representatives, many of whom had participated in their development (Braun et al. 2003). Photo 3.1 was taken at one of the PRA workshops with members of the Asbestos Interest Group of Kuruman and shows the author and AIG members reviewing and discussing the results of the initial desk-top level assessment.

Photo 3.1: Members of the AIG reviewing the initial desk-top mapping completed by the author (photo by Robert Jones)

Figure 3.2: Location of known asbestos mines and dumps within the Northern Cape per the DME database with a five kilometre radius

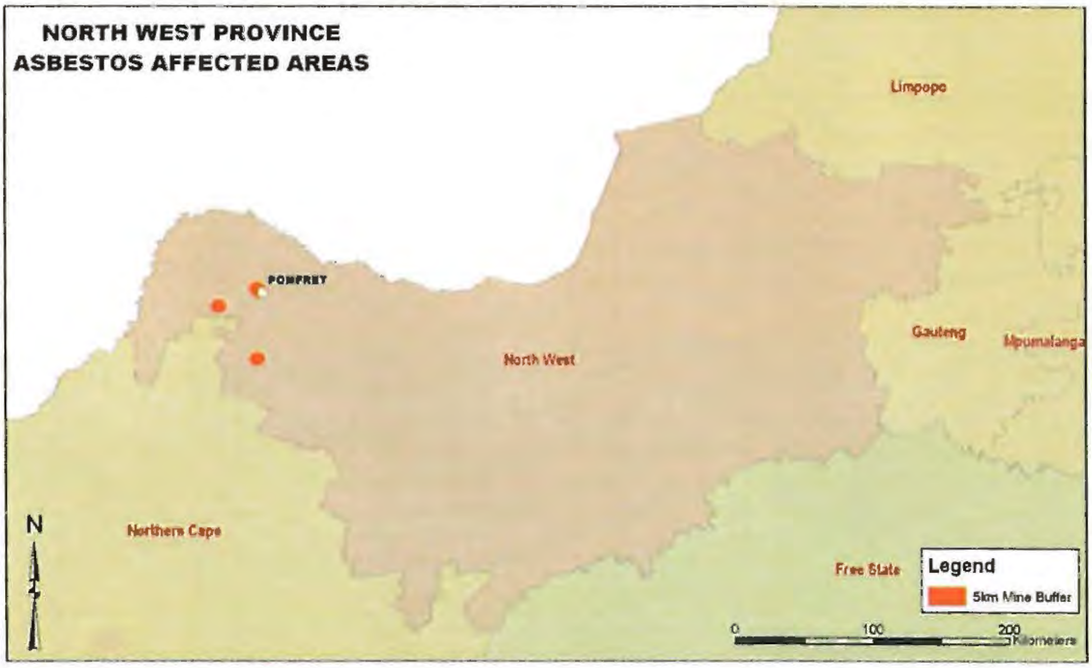


Figure 3.3: Location of known asbestos mines and dumps within the North West Province per the DME database with a five kilometre radius

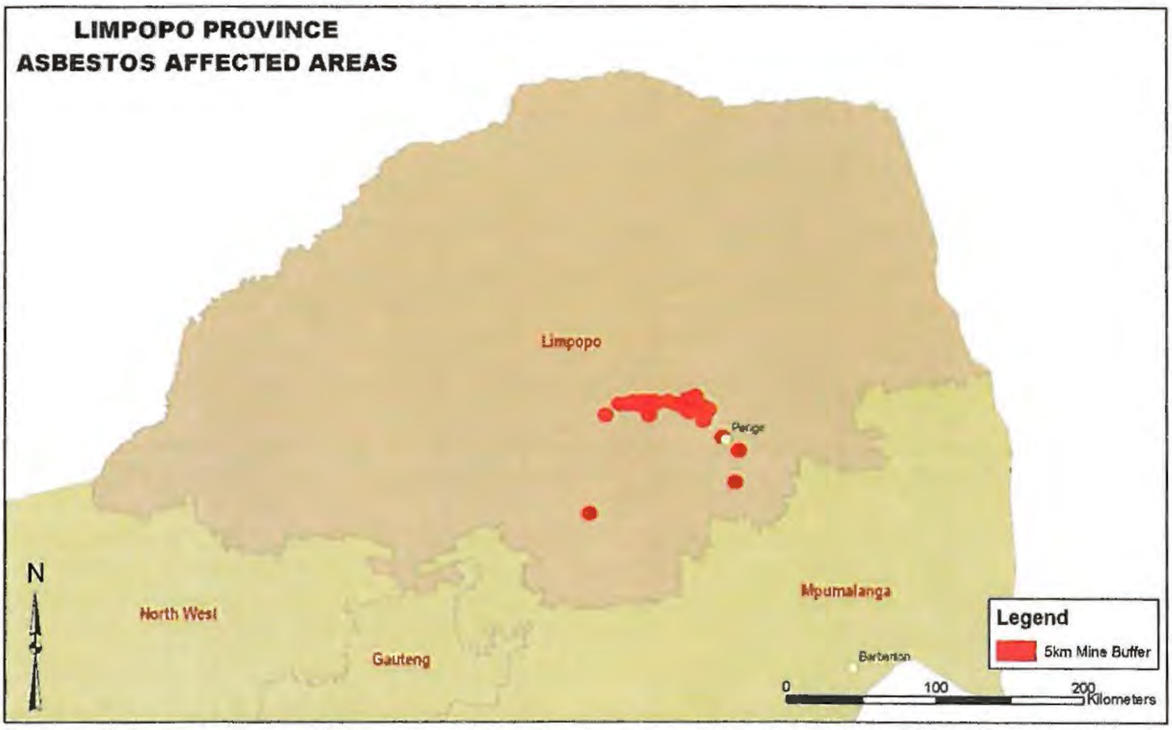


Figure 3.4: Location of known asbestos mines and dumps within the Limpopo Province per the DME database with a five kilometre radius

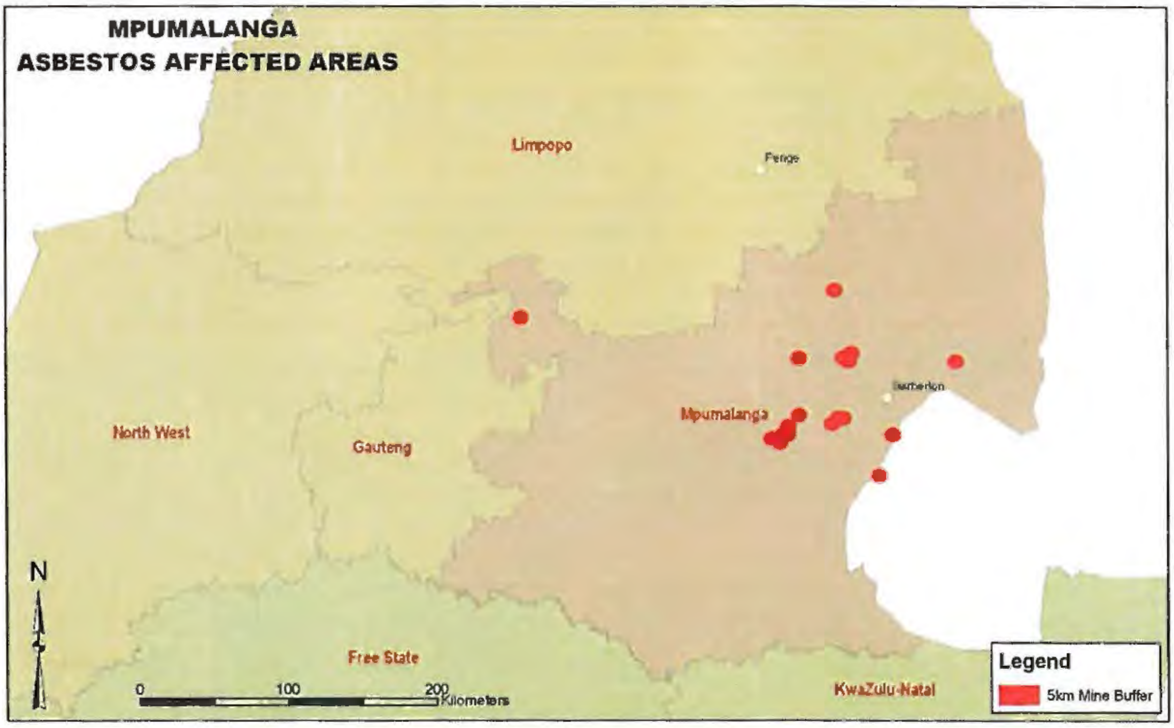


Figure 3.5: Location of known asbestos mines and dumps within the Mpumalanga Province per the DME database with a five kilometer radius added

The initial desk-top assessment identified 80 locations of potential sources of contamination within the Northern Cape and North West Provinces with 41 communities within a five kilometre radius. Of these 25 (61%) were identified as a High Priority for field level assessment based on the above criteria. Within Limpopo and Mpumalanga there were a total of 57 sources and 27 communities within the five kilometre buffer, of which, 19 (70%) were identified as a High Priority for field level assessment (not reported as part of this research). This coarse level of assessment yielded a total of 44 (65%) communities to be targeted for field level assessment (High Priority), out of the total potential of 68 within the five kilometre study limits. Since the date of the initial assessment the Northern Cape boundary has been extended and it now includes all but one of the surveyed communities formerly located in the North West Province (Pomfret).

Figures 3.6 through 3.8 are examples of the results of the initial desk-top preliminary risk ranking. Figures 3.6 and 3.7 are typical of communities that were ranked as a Low to Moderate Priority due to the distance from the mine site (identified as a green centre point) to the nearest population centre (identified as a pink area). The Mine 387 Map (Figure 3.6) is a typical example of a mine site where no community exists within a five kilometre buffer and thus the area was classified as a Low Risk site based on the initial desk-top level assessment.

The Owendale Map (Figure 3.7) indicates that the nearest community is just beyond the five kilometre limit however, there are identified paths (both man-made tracks and drainage courses leading from the potential point source towards the community). This community could then be rated as Low Risk but given the close proximity of the village (just at the edge of the five kilometre radius) and the existence of drainage/travel paths, it could also be included as a Moderate risk community. In order to verify the correct classification the author completed a field inspection which revealed the access is fenced and the community does not likely have extensive asbestos contamination. The predominant building materials were non-asbestos commercial products (as opposed to locally made materials) and the roads were predominantly tarred.

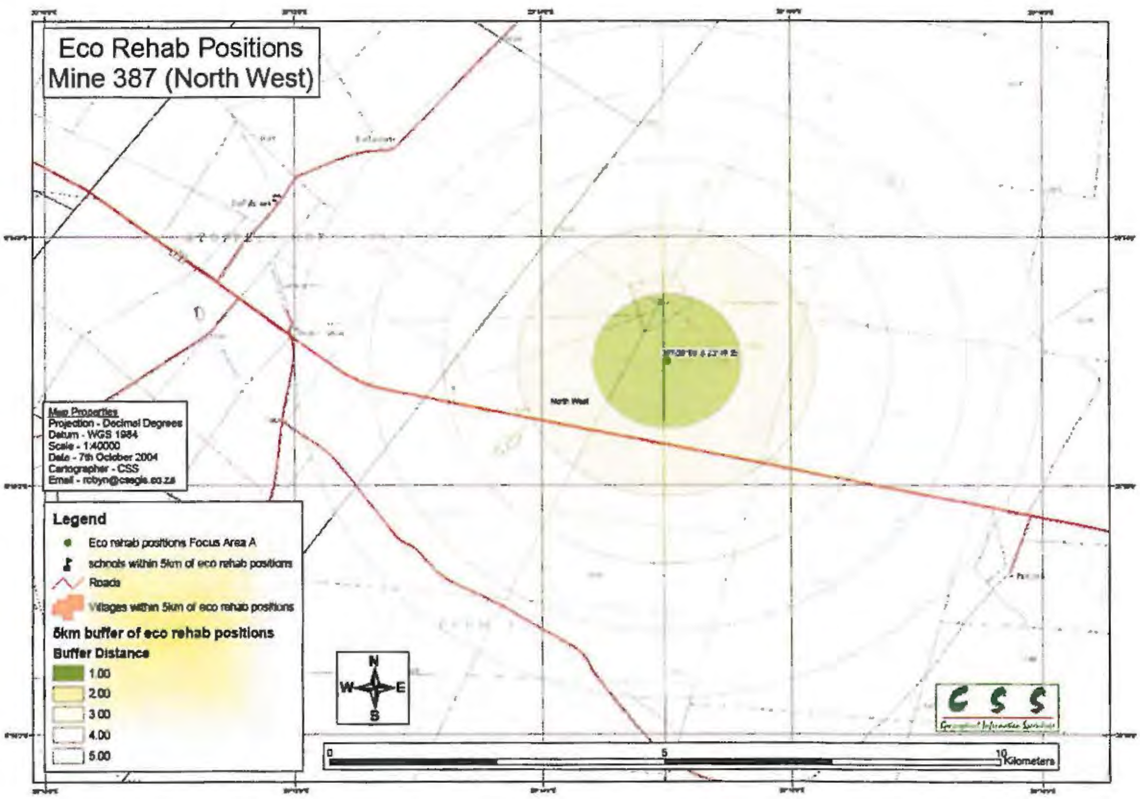


Figure 3.6: Map 387 – Low Risk Classification from desk-top level assessment

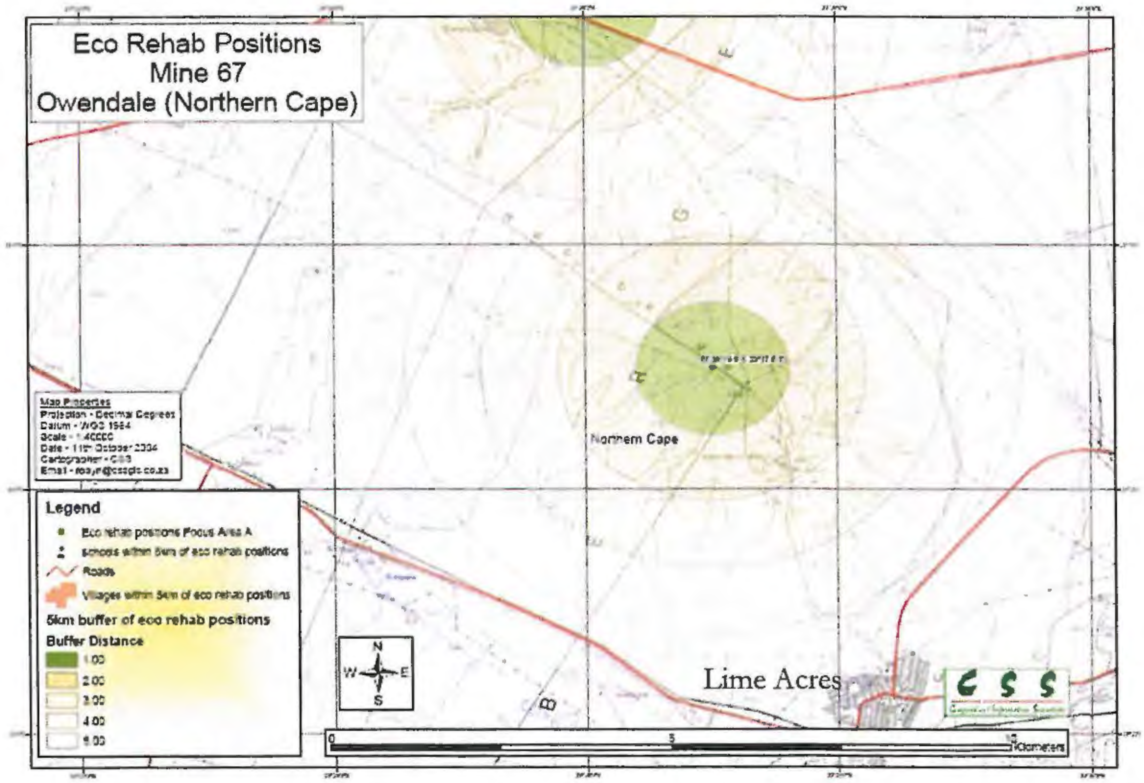


Figure 3.7: Mine Site 67 is typical of a Low to Moderate Priority survey region in the Northern Cape. Note the nearest community (Lime Acres) is just beyond the five kilometre radius.

Figure 3.8 is typical of villages that were identified as a High Priority as a result of their proximity to multiple mine and/or dump locations. Within this example seven communities are located within a two kilometre radius of the identified mine/dump sites and three within five kilometres that are classified as Moderate Priority.

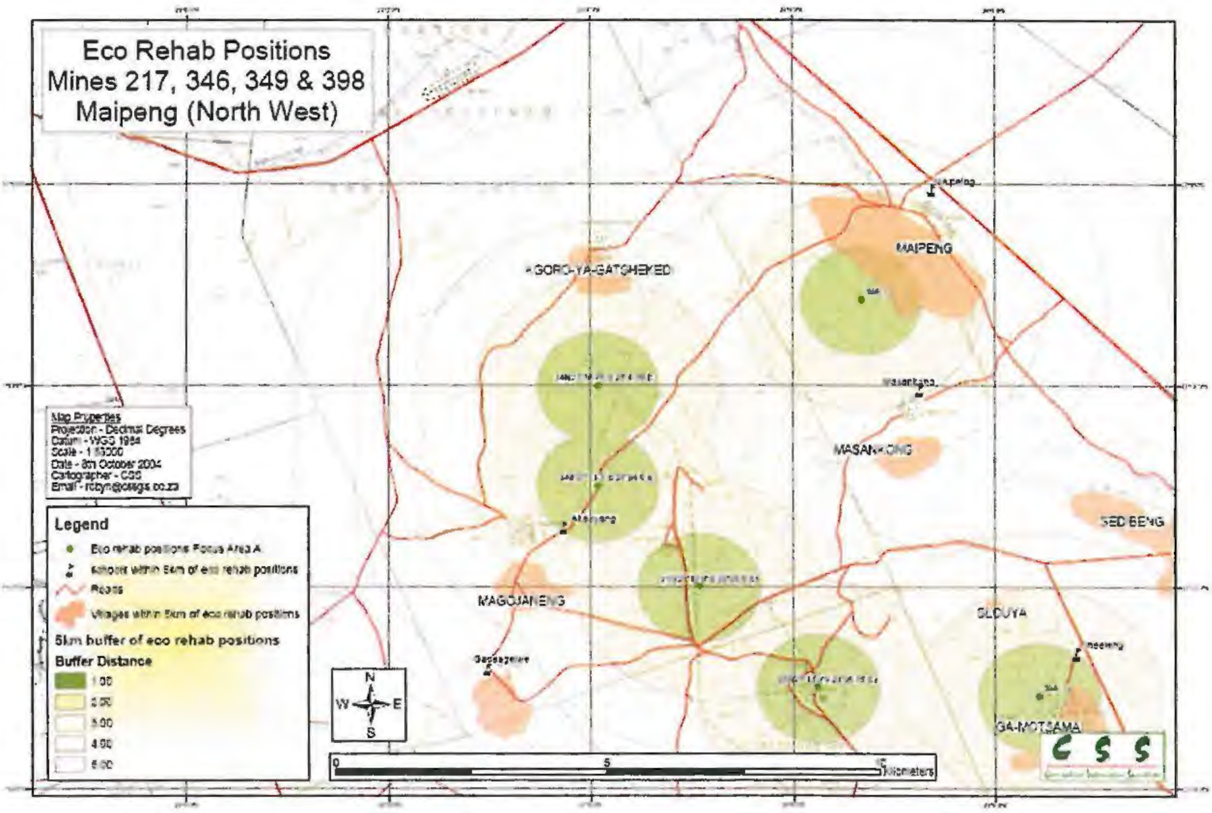


Figure 3.8: Maipeng Map typical of a High Priority survey region (Northern Cape) with multiple villages within close proximity (less than two kilometres) to numerous mine and dump sites.

Based on the results of the desk-top level assessment, augmented by the RRA mapping exercise, a total of 36 communities in the Northern Cape and North West Provinces (Study Area) were identified for more detailed assessment with eleven of these outside of the initial five kilometre risk buffer but reported by the local facilitators. This represents a 44% increase over the initial high risk classification completed by the desk-top analysis alone thus representing the importance of obtaining local community input into the process. Table 3.3 identifies those communities and Figure 3.8 their mapped locations where this research indicated the completion of more detailed field level assessments was justified.

Table 3.3: High or Moderate Risk Communities Surveyed and Justification for Selection within the Northern Cape and North West Provinces

COMMUNITY	JUSTIFICATION FOR SELECTION	COMMUNITY	JUSTIFICATION FOR SELECTION
Kuruman	Greater than 5km of source but reported by facilitators	Ga-Motsamai	Within 2km of source
Wandrag	Within 2km of source	Heuningvlei	>5km but reported by local facilitators
Wrenchville	>5km but reported by local facilitators	Ga-Sehubane	Within 2km of source
Owendale	Within 2km of source	Gatshikedi	Within 2km of source
Westerberg	Reported by local facilitators	Masonkong	Within 2km of source
Koegas	Within 2km of source	Mothibistad	Reported by local facilitators
Draghoander Station	Within 2km of source	Ncweng	Within 2km of source
Prieska	Within 2km of source	Pietboos	2-5km with paths to source points and reported by facilitators
Jenhaven	Within 2km of source	Pomfret	Within 2km of source
Groenwater	Within 2-5km of source	Magojaneng	Within 2km of source
Warrendale/Lime Acres	Within 2-5km of source	Tshukudung	Reported by local facilitators
Bankhara	Greater 5km but reported by facilitators	Tsineng	Reported by local facilitators
Bodulong	>5km but reported by local facilitators	Vergenoeg	2-5km with paths to source points
Batlharos	Reported by local facilitators	Maruping	Reported by local facilitators
Galotolo	Within 2km of source	Magobing	Reported by local facilitators
Seodin	>5km but reported by local facilitators	Maipeing	Within 2km of source
Sloja	Reported by local facilitators	Sedibeng	Within 2-5km and reported by local facilitators
Ga-Mopedi	Within 2km of source	Seven Miles	Reported by local facilitators
Total Communities: 36			

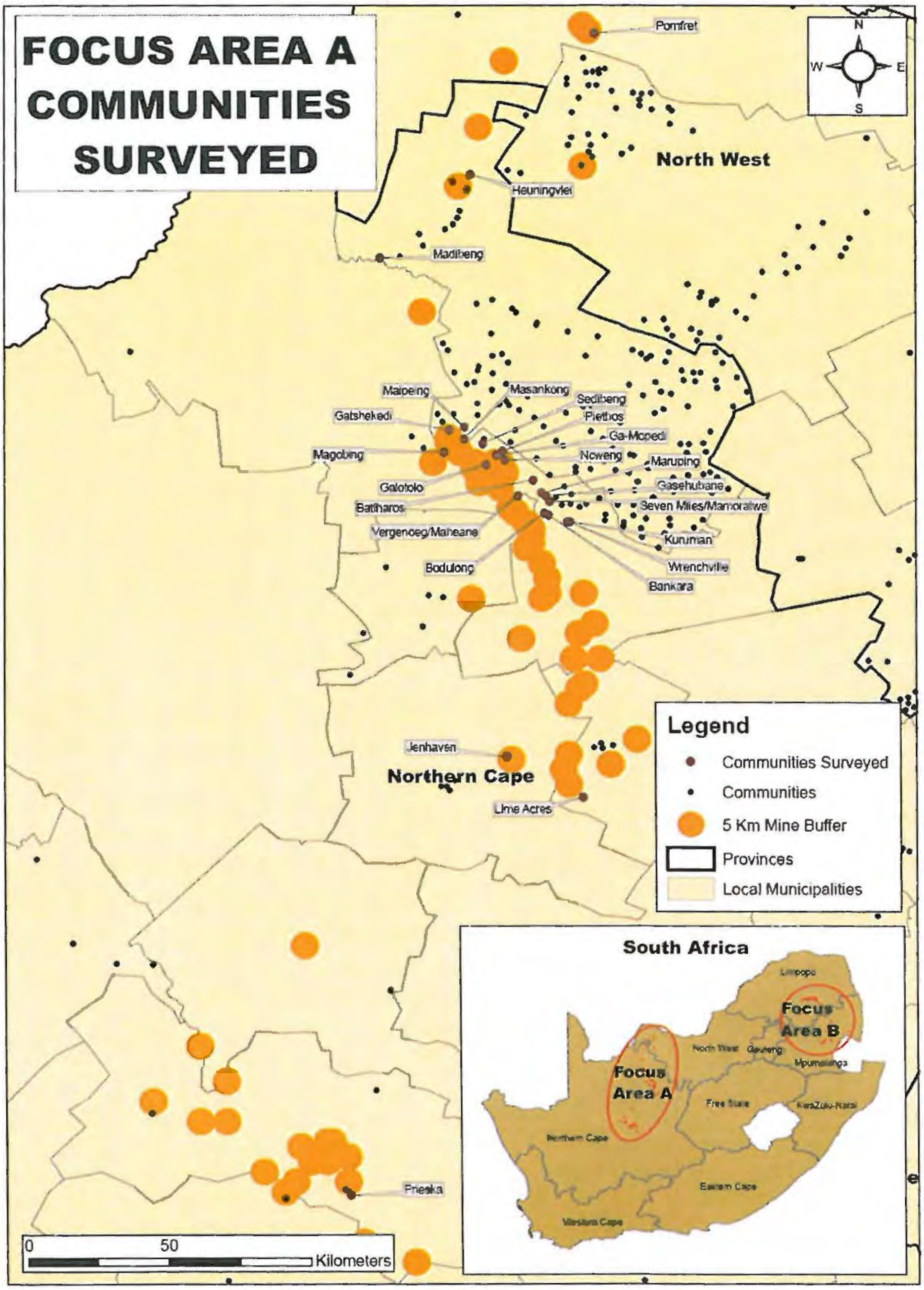


Figure 3.9: Map of communities surveyed in the Northern Cape and North West Provinces

The Study Area was selected as the 36 communities identified as High or Moderate Risk within the Northern Cape (new boundary) and North West Provinces. Felix (1997) surveyed the 27 villages of Ga-Mafefe (Limpopo Province) using 1 780 questionnaires of the residents to estimate the extent of asbestos containing building materials. Those results are used as a comparative model to this research.

3.4. Methods for the identification of those locations within each community that were suspected for environmental contamination

The approach used in this part of the research is one of increasing refinement from the initial coarse characterization of the potentially impacted regions down to the community level for the initial risk assessment and prioritization. From this point a variety of methods for sampling and analysis were considered. The laboratory methods for sample analysis methods are discussed in Chapter 4.

It was determined that in order to more accurately quantify the extent and severity of environmental asbestos contamination the high risk communities identified by the desk-top risk assessment would be sampled and mapped in the field by both the lead investigator and trained community representatives. Eight "community facilitators" (seven from the Asbestos Interest Group and one from Ban Asbestos First) were selected for training. These two groups are actively working on community level asbestos issues within the Northern Cape. Training was provided by the lead investigator and included the appropriate methods of sample collection, health and safety precautions and general knowledge of asbestos. The training was modelled after the Asbestos Hazard and Emergency Response Act (AHERA) three-day Inspector course. A training manual was also provided to each member along with all necessary personal protective equipment (PPE). This included an approved face mask, gloves, tools, spray bottle, sample containers, maps, a handheld global positioning system (GPS) receiver, survey forms and other necessary equipment.

The author and AIG Coordinator also provided liaison services with the local communities targeted for surveys. This typically involved first meeting with the local headman or chief to inform them about the nature of the survey, its necessity and what possible outcomes could be expected. This proactive dialogue was an important component of the field work for a variety of reasons. Payne-Sturgis et al. (2004) have documented a number of concerns raised by communities that are subject to environmental or public health surveys. A primary concern is a lack of communication between the researchers and community members and a lack of follow-up as to the outcome of the investigations and its implications for those affected. In order to overcome this issue the author appointed the community facilitators as representatives of the research team and to accompany him with part of their responsibilities being to inform the traditional leadership concerning the nature of the survey work within their community. By making a point to contact the local traditional leader the research team was showing deference to the local culture and re-affirming the existing hierarchy of authority.

Decisions affecting communities are often made by governmental authorities with little if any local engagement. This research was being sponsored by the national government and the research team was in affect acting as the government's agents. It was anticipated that future clean-up activities may be initiated by the government as a result of the surveys and these will cause major disruptions to the affected communities. These disruptions could be exacerbated by a lack of trust and poor communication between the parties. By engaging with the appropriate community authorities at this early stage it is hoped that the groundwork was being laid for better communication between government agents, contractors, researchers and community members when decisions regarding remediation are made. The lead investigator attended a number of these meetings, however, the local facilitator, often the AIG Coordinator acted as the primary agent. This allowed the meetings to take place in the language most appropriate to the members (often Tswana or Afrikaans). The community engagement process continued throughout the duration of the research.

The selection of particular sites within each community to survey by bulk sample collection was developed from the following protocol during discussions with the local community representatives and facilitators. In order to do so, a non-random sampling approach was utilized. The approach sought to target those areas most likely contaminated by asbestos through a combination of pathways including:

- Buildings and sites that were known to local individuals within the community to have used asbestos in the construction of buildings, stands, where contaminated soil may have been used in gardens, roads or other sites suspected of being contaminated with asbestos waste. Sites that were deemed to be typical of a particular type of construction or one of a number of sites that were considered to be reflective of a larger sample set were given priority.

While this approach does not lead to unbiased randomized sample sets, it is more consistent with the goals of this research in that it sought to target those areas most likely to be contaminated. It does not allow however, for a linear extrapolation to the larger data set of land use categories such as households. It relied heavily upon the existing knowledge base within each community as communicated through the interview process with the local traditional leaders and from the previous RRA experience of the facilitators. Corburn (2002, p. 246) states that, "community knowledge is essential for understanding environmental hazards and for developing contextually relevant interventions to eliminate the hazards". Local people have a "privileged" knowledge and understanding about the places where they live (including potential environmental hazards) and researchers should seek to utilize organizations already established in those communities.

The facilitators were divided into teams of two, one team surveyed the villages in the vicinity of Hueningvlei (North West Province), and two teams surveyed the villages north of Kuruman (North West and Northern Cape Provinces). One individual, accompanied by the author surveyed the vicinity of Prieska. The author and two AIG facilitators surveyed multiple sites in Limpopo and Mpumalanga Provinces over a period of three weeks. The author accompanied facilitators on numerous sampling events in addition to individually conducting sampling at a number of locations in all four Provinces over the course of the research. The initial community survey by AIG was completed in 2004 and 2005. Samples were sorted, packaged and couriered to the author in February of 2005. Sample locations, dates, sampler identification and material type was recorded on the sample data forms and transferred to the sample database.

At each sampling location where appropriate the facilitators conducted an interview with the local residents during the community surveying programme. The purpose of the interviews was to gain additional understanding about the potential for asbestos contamination in the area and to explain the reasons for the community surveying effort. Questions dealt with the type and date of construction of the buildings being surveyed, the use of asbestos materials, their source and the existence of any mining activities or dumps in the vicinity. There is considerable interest amongst residents in the area concerning the disposition of lawsuits, settlements and potential government compensation due to the extensive environmental contamination and health impacts. The AIG facilitators are experienced in answering these types of questions and the community survey programme provided an opportunity for information sharing and education of local residents. At each site to be sampled, the facilitators completed a site data form designed to capture information relative to the use of asbestos on the premises, the conditions of the contaminated area and its potential for exposure to residents or other individuals (see sample in Appendix A). Additional information included the sample locations, site address, ownership and date of construction. A site sketch was completed on the back of the site data form to record the sample locations, site features and to help guide future interventions or remediation measures. Additional methodology is provided in Section 5.2.

3.5. Results for the identification of those land uses and locations within each community that were suspected for environmental contamination

A community survey programme was developed to identify those land uses and locations thought to be representative of the conditions experienced in the majority of the communities selected above (Table 3.3) for more detailed assessment. It was recognised that the community sampling programme could not sample all known or suspected locations of contamination within the study region therefore the following protocol was developed for this research to establish those land uses where sampling would take place. These comprised land uses that represented consistent use by the public and that were representative of those commonly found within other communities in the Study Area. In a descending order of based on their occurrence, the following land uses were identified for surveys:

- Homes (represent the largest single land use type within the Study Area)
- Schools (represent significant duration of occupation and use by sensitive populations - children)
- Dirt roadways within communities (utilized by individuals as pedestrian ways and passing vehicles generate copious amounts of dust)
- Public buildings in communities that are accessible to the general public
- Private buildings and businesses (those accessible to the general public)
- Churches
- Active open spaces, playgrounds, sports grounds, etc
- Other less used spaces such as open veld, cemeteries, etc

Within each of these land uses, sampling was completed at sites where asbestos waste was suspected to have been purposely used as a building material, ground cover, fill or was inadvertently placed. The surveys concentrated on specific land uses that represented the communities within the region. Residences were most frequently identified as sites for detailed assessment (58%), followed by schools (11%), roads (10%), public buildings, including tribal halls, clinics, police stations and post offices, (6%), private businesses (4%), churches (3%), playground and sports fields (3%), and other (railways/stations, cemeteries, and open veld) at 5%. A summary of the 437 locations surveyed categorized by land use is provided in Table 3.4.

Table 3.4: Summary of sample locations identified for detailed surveys per land use

LAND USE CATEGORY	STUDY AREA
Homes	259
Schools	45
Roads / Streets	29
Halls / Administrative and Tribal Offices	17
Private businesses	16
Other or undetermined (for example open spaces, veld or commons)	14
Churches	11
Hospitals / Clinics	7
Rehabilitated and Unrehabilitated dump sites	7
Playgrounds / Community Parks	5
Police Stations / Post Offices	5
Railways / Railway Stations	4
Graveyards/Cemeteries	3
Totals:	**422**

3.5.1. Residential land uses

The largest numbers of buildings within a community are residential and it was therefore considered that they should be a primary focus of the sampling effort. Homes were selected for screening-level surveys based on a number of factors.

1. They represent the largest single land use category in terms of the number of buildings.
2. Homes are occupied by a variety of receptors ranging in age, sex, ethnicity, occupation and socio-economic status. Homes include (or have the potential to include) children. Age of first exposure is an important determinant in asbestos disease risk.
3. Exposures to asbestos in homes can range from zero to low constant levels and there are likely to be episodic events that may substantially increase airborne concentrations of asbestos.

4. Individuals who may be occupationally exposed to asbestos may also be exposed at home and these factors need to be accounted for in risk models.

As shown on Table 3.4 a total of 259 homes were targeted for detailed surveys within the Study Area. Previous reports (Braun et al. 2003; Felix 1997) have stated that local residents often use raw or waste asbestos in the construction of their homes. This is particularly noted in the villages closest to the existing mines and tailings dumps. Felix (1997) provided the only quantitative assessment of this practice in the former mining areas relying upon questionnaires to report the use of asbestos in and around homes. The survey approach was to represent existing housing stock where asbestos contamination was suspected and therefore the results are not a random survey of homes in these communities.

There are no large scale assessments of homes with asbestos contamination from which to draw inferences for potential rates of asbestos containing materials. The US EPA (1988) estimated that 59 percent of residential apartment buildings in the U.S. (with 10 or more units) contain some type of asbestos. Over one million low-cost homes in South Africa may contain asbestos roofs (FRIDGE 2002). Australia reports that as many as one in three homes built before 1987 could contain asbestos (Mail and Guardian 2004). A recent survey of the Thetford community located adjacent to the Thetford chrysotile asbestos mine revealed that nine of 26 homes surveyed (35%) contained asbestos contamination (Marier et al. 2007). The phase one survey of potentially contaminated sites in Libby, Montana by the US EPA (2001) indicated an overall contamination rate of 62 percent (162 of 263 properties).

This research represents sampling of existing housing stock where asbestos contamination was suspected and it is therefore not a random survey of homes in these communities. The percentages of contamination that are identified may not represent communities within the region where there is less evidence of contamination. However, sample size is significant, and more importantly, the potential exposures of asbestos dust to the inhabitants is a major community health concern.

3.5.2. Schools

Schools are a primary concern for exposure to asbestos for reasons stated above related to childhood exposure and also for potential exposures to workers (teachers, administrators and custodial staffs). The US EPA in a 1984 survey estimated that 35 percent of the public schools in the U.S. contain friable asbestos containing materials (USEPA 1984). School based exposure to friable asbestos (0.005 mixed f/ml longer than 5 µm) for six-years from the age of 5-11 (180 days/year, 5 hours/day) was estimated by the US EPA to increase the risks from lung cancer and mesothelioma to approximately 30 cases per million exposed population for learners and for teachers over a twenty year work period to 80 cases per million exposed (HEI-AR 1991). A similar study was completed for school exposures in Ontario, Canada by Hughes and Weill 1986 with similar results reported (within the same order of magnitude). These calculated exposures and risks were partially responsible for the adoption of the US Asbestos Hazard Emergency Response Act (AHERA) of 1986.

No published survey of air concentrations within South African schools was ascertained by this research. The Municipal Demarcation Board and Department of Education include a description of building materials for wall types and roofs for schools within South Africa (South Africa Municipal Demarcation Board 2000). The data set is incomplete in that not all schools are described in this manner for the four Provinces surveyed as part of this research. Asbestos was not listed as a potential listing for, "wall type" and therefore its presence may not have been surveyed for as part of the data collection effort. Asbestos was listed as potential "roof type" and therefore these records were queried. Of the 6,871 entries reviewed, 134 were identified as containing an "asbestos roof." No data are provided as to the condition of the building materials.

A total of 47 individual schools including day-cares and pre-schools were targeted for more detailed assessment as part of the community survey within the Study Area. Felix (1997), in her survey work included a total of twelve schools. This survey does not represent a comprehensive study of the schools within the affected region nor does it represent a comprehensive survey of any individual site. It rather serves to highlight the incidence of asbestos contamination (from either soils and/or building materials) at schools within the distances identified by the preliminary risk mapping and/or the judgment of the community inspectors.

3.5.3. Roads

The John Taola Gaetsewe District (formerly the Kgalagadi District)) Council completed a study of roads within the Kgalagadi and Karoo Districts of the Northern Cape (Viridius Technologies 2002). This study was comprehensive in nature and included a total of 838 soil samples and 399 air samples. According to the results of the study, "all roads... were found to have some degree of pollution" (Viridus Technologies 2002, p. 65). The results also indicated no significant differences between contamination found in the road foundation, windrows and secondary pollution within the road reserve. In addition, the survey identified sections of road that had most likely been reconstructed with asbestos polluted material versus those sections where isolated occurrences of either road repair or spillages had occurred. The air sampling yielded a total of 58 samples (15%) above a 0.8 f/ml cut-off used in the study based on a modified RTM1 analysis methodology. It is noted that the sample period was significantly shortened from a minimum recommended period of 60 minutes to 10 minutes. According to Castleman (1996, p. 333), the settling speed of a fibre visible under phase contrast microscopy is on the order of 30cm (one foot) per hour. Thus a longer sampling period, consistent with the 60 minute recommendation may have yielded slightly lower results given the higher volume of air passing through the filter however it is likely that even after one hour it would still be possible to detect asbestos fibres in the breathing zone. In addition, as is stated in the Kgalagadi report, the RTM1 methodology is not the most accurate method of counting asbestos fibres. Methods that utilize scanning or transmission electron microscopy will yield more reliable data for purposes of assessing risk. The current South Africa OHSA occupational limit for a 4 hour time weighted average is 0.2 f/ml (OHSA 1993) considerably lower than the threshold used in the study of 0.8 f/ml.

A total of 29 roads were identified for sampling as part of this research. The majority of roads (27) were unpaved and thus very dusty, particularly during the dry period.

3.5.4. Public buildings and places

The US EPA classifies asbestos containing materials in public buildings into three categories: miscellaneous products (floor and ceiling tiles, acoustic plaster, cement tiles, etc), insulation for pipes, boilers and tanks, and sprayed surface treatments (USEPA 1985). Sprayed asbestos materials are generally friable and susceptible to fibre release in ambient air when damaged or merely touched (Institut National de Santé Publique du Québec 2004). These categories are not applicable to South Africa, in particular, boiler units and pipe insulating materials (now referred to as thermal system insulation or TSI) are not prevalent, particularly in the more rural areas assessed by this research. Additionally, with the exception of asbestos cement products, the presence of asbestos containing ceiling or acoustical tiles is not common either. Sprayed asbestos was also not identified within the public buildings assessed as part of this research. However, the tendency of sprayed asbestos to be friable and to easily dislodge into airborne fibres is consistent with many of the building materials assessed as part of this research. Plaster and bricks/blocks with locally obtained materials and locally constructed are often in poor condition, lack a sealant type exterior coating, are subjected to harsh elements (sun, wind, erosion, etc) and are thus very friable and capable of releasing fibres into the atmosphere when brushed or disturbed.

Episodic exposures from disturbing sprayed or building materials that exhibit similar responses to disturbance may yield significant, albeit short-term exposures to workers or building occupants. As early as 1971 surveys showed that brushing sprayed on insulation with crocidolite could result in airborne concentrations of 11.9 f/ml as measured by PCM and that dusting a surface contaminated by chrysotile could lead to exposures of 15.5 f/ml (Sawyer and Spooner 1979). For these and other reasons, sprayed asbestos insulation was banned in the United States in 1973, in Iceland in 1983, the U.K. in 1985, France (all uses) in 1997, Canada in 1989 (with a voluntary ban in 1973) and in South Africa (all uses) in 2008. Many other countries have completely or partly banned asbestos use (most having banned the amphiboles first with many other also banning chrysotile.

A total of 29 public buildings, (community halls, tribal offices, hospitals, clinics, police stations, and post offices) were targeted for detailed sampling as part of this research.

3.5.5. Less frequented locations

A total of 330 locations (open spaces, parks, un-rehabilitated dumps, rail stations, and graveyards were also surveyed within the Study Area. Private businesses were not proposed for significant sampling unless they were accessible to the public (such as small tuck shops or bottle stores). A total of 16 individual locations were surveyed within the Study Area. The potential for non-mining related occupational exposures to asbestos is regulated by the South African Department of Labour and was thus not within the scope of this research.

3.6. Bulk sample collection at individual sites within selected communities

The geographical extent of environmental contamination in both building materials and soils cannot be determined without direct site specific sampling and laboratory analysis. The methods and results described in Chapter 3 defined the geographic extent of community surveys conducted by this research. Bulk samples, for this research, include building material specimens and soil. The method of site sampling selected for this research is characterized as a "screening-level assessment" as it sacrifices a high level of confidence for a much broader area of characterization. Bulk samples were collected at each location per the protocol described in Section 5.2. Samples were sorted, packaged and couriered to Rhodes University (RU) and Nelson Mandela Metropolitan University (NMMU) for laboratory analysis. A total of 2 059 samples were collected during the community survey work in the four Provinces. Each discrete sample collected in the field was logged into a project database. Once at the laboratory, all samples were analysed according to the procedure described in Chapter 4.

The US EPA (1988) recognised four indicators for estimating possible exposure to asbestos from contaminated buildings. These are:

- Presence (summarized as the amount and type of asbestos containing materials (ACM)
- Condition of the ACM
- Location of the ACM
- Estimated airborne asbestos concentrations

These indicators are also important in the assessment of environmental contamination and were modified and described below. The data collected during the community surveys can be summarized under three broad categories based on the initial research objectives:

1. the determination of the geographical extent of environmental contamination in both building materials and soil with respect to an initial point source identified by the DME RPI database;
2. the relative severity of the contamination as a function of its concentration (within soil and building materials); and
3. the condition of the material (defined by its friability or potential friability) and the extent to which the material may be accessible to or disturbed by humans and thus lead to potential asbestos inhalation exposure.

3.6.1. Soil sampling

The site specific surveys within each community were conducted at a screening level designed to assess the largest number of sites possible within the confines of the selected method. The relative severity of contamination is a function of the percentage of sites that are contaminated with asbestos and the degree of the concentration of asbestos contamination in a given sample. This is important in that the percentage of contaminated sites versus sites with no asbestos detected (NAD) can be used to extrapolate to the total number of potentially contaminated locations.

The degree of contamination within a given sample is expressed as the percentage of asbestos fibres of a given sample compared to the total sample area analysed. This visual estimation is proxy for concentration of asbestos fibres and is used to estimate the potential for fibre release to the atmosphere. This research asserts that the greater the concentration of asbestos in a given sample, the greater the number of fibres of a respirable range that will be released due to disturbances or through environmental degradation. Therefore, it was necessary to define the geographical scope of sampling activities in order accomplish objective number 1 (extent of contamination) and a laboratory protocol and method to establish objective 2 (severity of contamination). However, as previously demonstrated, asbestos is primarily a hazard when it is inhaled and thus those factors that may increase the potential for fibres to be released in the atmosphere and inhaled are important considerations in determining overall risk. Those factors include the condition of the soil and building materials surveyed and the land use of the individual site within a community.

With respect to risks associated with the release of asbestos, soil conditions such as the extent of vegetative cover, its moisture content (a function of climatic influences) and physical properties (such as average particle size) all relate to its ability to generate dust. Bare or exposed soil is exposed to disturbances from wind and rain and to abrasion and erosion from vehicle and foot traffic, and animal traffic. Additionally soil that is not covered by vegetation is more likely to adhere to individuals' shoes, vehicle tyres and animal fur and thus contamination can be transported from one location to another.

3.6.2. Building materials

The condition of the building material is relevant to the potential risk of asbestos inhalation as a result of the following factors:

- Materials that are in a deteriorated condition are more likely to release fibres
- Materials that are accessible to occupants are more likely to be damaged or disturbed
- The location of the material and/or the use of the occupied space is a determinant for the potential for accessibility and disturbance.

The condition of building material is also relevant in the determination of overall risk of exposure. Building material condition was recognised as a significant factor in a comprehensive US EPA survey (EPA 1988) to determine airborne concentrations of asbestos. A total of 49 buildings (six with no asbestos containing materials, six with asbestos containing materials in good condition and 37 with damaged asbestos containing materials). The EPA reported an increasing trend in average airborne asbestos levels with the buildings containing damaged asbestos reporting the highest levels. According to Chesson et al. (1990) similar studies in Canada and the United Kingdom yielded comparable results.

The US EPA (1985a, 1985b, 1988) and Chesson et al. (1990) have documented that asbestos containing building material (ACBM) that is friable, in poor condition or frequently disturbed can lead to airborne concentrations of asbestos fibres. Additionally, soil that is contaminated with asbestos fibres can also lead to airborne concentrations and therefore where it is in close proximity to occupied dwellings, the prudent assumption is that exposures may be occurring on a regular basis. These exposures may occur on an almost continual basis for residents, including the elderly, children and home-based workers. For these reasons, it was considered important in this research to concentrate the effort on homes and gardens suspected of containing asbestos building materials or contaminated soils in close-proximity to previous mining or mine dump locations.

This type of assessment can be done using quantitative or qualitative methods. Current industry standards primarily rely upon qualitative assessments by trained personnel. The US EPA (AHERA method) has developed qualitative assessment methods along with ASTM International (E2356) (ASTM 2004a). These methods rely upon either an algorithm, a matrix or a decision-tree. The first algorithm was developed by Ferris for a survey of 1 425 schools in the U.S. State of Massachusetts (Irving 1980 as reported by the Institut National de Santé Publique 2004). The Ferris Index utilized five variables:

1. accessibility
2. condition of the material
3. friability
4. presence in ventilation ducts
5. asbestos content

A numerical score was developed that then guided the type of management needed to reduce risk. The US EPA adapted a similar algorithm adding the variables of, water damage and activity and movement of occupants, and exposed surfaces (ibid). In a study of the effectiveness of this method, Findley et al. (1983) found that the algorithm generally allowed observers with relatively little training to distinguish ACM in poor condition. The EPA later adopted a matrix approach that essentially utilizes two criteria, the potential for future disturbance (low or high) and the present condition of the material (good, minor damage, severe damage) (US EPA 1986a).

This research decided that the second, more simplified EPA approach was appropriate and incorporated the assessment of ACM into the training programme delivered to the field inspectors. The data form allowed the field inspectors to classify the building material's condition as, good, fair or poor. The following definitions were used in the training session to classify building materials based on these classifications:

Good: Building material that is not damaged, is well maintained, is painted or has surface coating to protect it.
Fair: Building material that has slight damage (small cracks, chips or exposed edges) or that has a small portion of the surface exposed from loss of paint.
Poor: Building material that has significant damage (large cracks, broken or missing pieces, holes), fragments of the material on the floor, deteriorating edges, delamination of layers, or exposed surface with damage.

3.7. Discussion

The initial desk-top assessment using geologic and topographic maps was useful for planning of community survey efforts and for determining those sites rated as low risk due primarily to their proximity to former mine and dump sites. Numerous dump and mine sites were located on farm land (mostly range land) in the Northern Cape and the maps indicated no communities, residences or farm compounds within the five kilometre buffer. A few maps did indicate the presence of farm compounds or buildings within the buffer and these were inspected wherever possible to ascertain if people were actively living in the area. While most of the home sites were ranked as a Low Risk due to their distance to the mine sites, they are not without risk. Farm residents, workers and occasional trespassers can and probably do come into contact with asbestos contamination. Additionally, animals grazing in these locations may transport fibres on their fur back to the residential compounds and kraals and thus exposing people who may not have had other environmental exposures to asbestos.

The methodology involving the five kilometre buffer yielded poor correlation to the actual communities that were surveyed in the Study Area wherein 35 percent (13 out of the 37) communities surveyed were located beyond the five kilometre radius. This highlights the importance of utilizing indigenous knowledge and site specific field inspections to assist and validate desk-top assessments. This difference can be attributed to a number of factors.

- This knowledge and experience are a distinct advantage in educating the general public about the health impacts of environmental asbestos exposure (Braun et al. 2003).

- Many of the communities selected for survey were within the proximity of more than one mine dump or mine site but outside of the strict five kilometre buffer. They are in close proximity to numerous potential sources of contamination and thus more likely to be contaminated than a community with access to only one mine or dump site (even at a closer distance). For instance, Heuningvlei is greater than 5 kilometres from the DME identified mine site but site inspections revealed that the DME location did not accurately reflect the extent of mine activities. An asbestos mill had formerly been located adjacent to the village and numerous dump sites still existed within close proximity to the residences. Bodulong is also located greater than five km from the nearest DME source point and the site inspection revealed the area to be contaminated while Bankara located approximately two kilometres further was found to not contain significant contamination.

Reliance upon the strict radius method would have missed a number of very contaminated communities and thus reduced substantially the validity of this research. This is the result of several inter-related factors.

1. The use of an arbitrary centre point to identify a mine or dump site is not accurate. Mines and dumps, in many cases, cover a large geographical area (several square kilometres). Also, given the history and range of mining techniques (from individual tributors to large commercial shaft mines), a more appropriate approach would be to field survey all visible remnants of mining activities and plot them using a polygon to identify the outer boundary. A buffer could then be calculated from the outer limits of the polygon.

2. The DME point files are not always accurate in that in some cases, there was no evidence a mine ever existed or no visible evidence of the former mine site could be found.

3. Local knowledge was important in determining the land uses and other activities that influence the spread of contamination. Distances from the source were important considerations, but other factors such as the accessibility of the site and other potential (closer) sources of building materials were also important considerations. Other factors included the use of intermediate stockpilers (or wholesalers) who would purchase the asbestos from small scale miners, then stock the material until sufficient supplies or prices were established for sale to the mills. These locations or stockpiles could contribute to the contamination within communities where they were located.

4. The transport routes for asbestos (either raw ore, hand-cobbed, or processed) are not accurately reflected on topographic maps. This information was more often gathered from local knowledge.

Combining local indigenous knowledge and proper field assessment yielded better results when used in combination with the desk-top level than just the desk-top approach by itself. As an initial screening tool is it useful but only if the radius is extended to encompass a larger number of potentially contaminated communities. This is largely the result of the utilization of a single source point as the centre point of the radii. It was determined through review of the topographic maps that mining symbols extended out from source points for several hundred or more meters at many sites. The use of a one kilometre circle as a starting point would perhaps be more appropriate with a five kilometre radius extending out beyond that (thus in fact creating a six kilometre radius). With respect to the Northern Cape and North West Provinces this would have picked up an additional number of communities such as Tsnineng which was included based on the local facilitator's knowledge or Mamoratwe and Geelboom which were not. In fact most communities that did not fall within the five kilometres radius are at a considerable distance from the identified source points with most being closer to ten kilometres. Thus the combination of standardized radius and local knowledge is the most appropriate approach for this level of assessment.

One potential source of data that was not used in this research and has since become more readily available is free or low-cost satellite imagery provided by on-line vendors. In areas where coverage is available, the images appear to show good correlation between major mining works and those mapped on the corresponding topographic series. These images can also provide a useful screening tool to identify communities, recently active, un-rehabilitated or recently rehabilitated mine works and physical paths such as trails, dirt roads, and topography. These can be very useful in the analysis described above but they still only serve to provide an alternative source for data, (albeit they are likely to be more up to date) than the traditional topographic maps.

Chapter four provides a discussion of the various methods surveyed and utilised in this research to assess the results of the detailed community surveys with respect to laboratory analysis. The methods range from coarse level visual assessment of the samples to sophisticated laboratory methods with the goal being to identify a method that is accurate and accessible to developing countries. The results of the sample analysis at the land use and community wide level are presented in Chapter five with the goal of identifying those communities that represent the extent of environmental contamination.

CHAPTER 4

4. VALIDATION OF TECHNIQUES FOR DETECTION OF ASBESTOS IN SOIL AND BUILDING MATERIALS

Shadows are fallin' and I'm runnin' out of breath
Keep me in your heart for a while
If I leave you it doesn't mean I love you any less
Keep me in your heart for a while[18]

4.1. Introduction

The previous chapter discussed the method and results of the community surveys for environmental asbestos contamination. The approach was one of refining the level of detail from a coarse assessment of potentially contaminated areas to site specific surveys designed to determine the actual levels of environmental contamination present within the communities. In order to analyse the large volume of samples generated by the site specific surveys it was determined that a sample analysis method that is reliable, efficient, cost- effective and did not require extensive training or technology was required. The South African Department of Environmental Affairs (DEA) requested that this research develop methods that met the principles of Best Available Technology Not Entailing Excessive Costs (BATNEEC). The selected method is consistent with this mandate.

A variety of methods were reviewed in the literature, however most were found to be impractical for the purposes of this research or were not consistent with the BATNEEC principle. The selected method of sample analysis followed a process similar to that employed for the selection of communities to be surveyed in that the initial screening level sample analysis was coarse with subsequent analyses completed at increasing levels of refinement in order to calibrate the results of the initial reporting. In particular, the ability to visually identify the presence or absence of asbestos was tested. This issue is important in that visual assessment is the current method used by the South Africa Department of Minerals and Energy (DME) for the identification of derelict and ownerless (these constitute the majority of remaining unrehabilitated sites) asbestos mines requiring rehabilitation.

[18] Warren Zevon, January 24, 1947 – September 7, 2003; died of mesothelioma. Lyrics to, "Keep me in your heart for a while" from the Album, *The Wind*. 2003 copyright Artemis Records, 2003

While there have been relatively few surveys of environmental contamination in South Africa, those that have been reported relied extensively or exclusively on a visual assessment approach (Felix 1997; Braun et al. 2003; Boysen 2004 pers. comm., 10 September; van der Merwe pc 2006; Donohue 2007). Other methods used to identify the limits for remediation of abandoned mine dumps have sought to identify where asbestos contamination is above a threshold value established as 1.8 percent "free" asbestos fibres or a computed average of 1.3 grams per kilogram (Boysen 2004 personal communication 10 September). The method used to establish the 1.8 percent free fibre level has never been published but was described to the author by the government contractor who developed it (ibid). It utilized a number of 100 kg bulk soil samples, run through a small commercial grinding and sorting mill (obtained from a defunct asbestos mining company), with the fibre collected on a sorting screen and then compared by a mass ratio to the original sample. Following concerns regarding the rehabilitation selection and decision-making process, a risk-based Rapid Priority Index (RPI) was introduced (*Ibid.*, Braun et al. 2001).

Concerns as to the adequacy of this procedure due to an inability to replicate its method and sensitivity have been raised (Jones 2004). The current methodology for selection of mine sites for rehabilitation (also unpublished) depends upon a visual determination of fibres (assumed to be asbestos) present in the surface soil including off-site migration of fibres along stream courses and onto adjacent lands. In this method a field inspector will walk from a known point source of contamination (such as a tailings pile or mine dump) away from the source visually assessing for the presence of fibres or asbestos debris on the ground surface. The limits of contamination are then determined to end at the point where fibres or asbestos debris are no longer visible to the naked eye. The extent to which the DME Contractor will then consider conducting a clean-up of these secondary areas is determined on a site-by-site basis using the Rapid Priority Index (RPI) as informed by this visual assessment method (van der Merwe 2006 pers. Comm., 15 June). Therefore, one of the objectives of this dissertation is to determine if visual assessment of soil and building material media can accurately determine the presence or absence of asbestos fibres.

The visual assessment of asbestos in soil and building material (bulk samples) can be problematic for a variety of reasons. First, the respirable size class of fibres cannot be seen with the naked eye. Generally, the eye cannot see an object thinner than approximately 30-40 μm or about ½ the thickness of a human hair. One fibre of this diameter could actually contain up to two million individual fibrils (McCulloch, 2002)[19]. Depending upon the range of fibre sizes, the total number of asbestos fibres in a gram solid (assuming the mass of amphiboles) can range from 73.5×10^9 to 7.5×10^{13} (Jones 2004). The standard size classification for South African amphibole in the Cape Province was reported by Shedd (1985) and Wylie (1988) as quoted by Chisholm (1995). Fibres tend to be short (>98.4 percent are shorter than 10 μm) and narrow (>98.5 percent less than 0.4 μm in width) with airborne concentrations similar in proportion to bulk samples. Assessing only those fibres that may be biologically active, using Stanton et al. (1981) aspect criteria, six percent from raw bulk samples and 14 percent of milled samples met the criteria (>8 μm in length and <0.25 μm in width) (adapted from Shedd 1985, p. 18). Given these size classifications, the vast number of asbestos fibres present in any given sample will not be visible to the naked eye. Therefore, the lack of a visual indication of asbestos does not conclusively indicate the sample is free of asbestos content, but only that no asbestos is detected given the limitations of the method of analysis which in the case of visual assessment, may be significant.

Asbestos fibres tend to divide longitudinally into ever increasingly smaller fibrils (to a minimum diameter of ≈ 0.02 μm) (Perry 2004). Given this propensity they can easily become airborne when agitated (Davies et al. 1996). They can therefore be present in quantities that can lead to airborne concentrations approaching occupational or regulatory limits and still be invisible to the naked eye in the soil or building material matrix. The U.S. EPA (1997) estimates that 30 million asbestos structures longer than 5μm in length per gram of solid may potentially pose a cancer risk exceeding 1×10^{-6}. However, even at that quantity, within any given soil

[19] McCulloch's calculations may be off by a few orders of magnitude. Given the mean diameter of an asbestos fibril (Kuruman sample) per Shedd (1985), a visible fibre bundle will contain ≈ 2,000 individual fibrils.

or building material matrix, it is unlikely that the material will be visible to the naked eye[20].

The sensitivity of the method is therefore the most important consideration in the determination of a method to identify asbestos in a given soil or bulk material sample. In the context of this research it was determined that the method must be sensitive enough to quickly and efficiently identify asbestos within soil and building materials at a level that could represent a health hazard if the fibres within a respirable size classification are released into the atmosphere. Exactly what level this represents is a much debated topic. For instance, recent studies show that soil tremolite asbestos levels as low as, 0.08% are found to generate airborne exposures exceeding the U.S. occupational permissible exposure limit of 0.1 f/cc (Miller 2008). According to the California Department of Toxic Substances Control, low levels of asbestos in soil can yield significant air emissions as a result of soil-agitating activities (Collier 2003).

The definition of a regulated asbestos containing material in the U.S. had led to further confusion as to what may constitute a "safe" level of asbestos contamination.[21] The U.S. Asbestos Hazard Emergency Response Act (AHERA) was enacted in 1986 to protect children from asbestos contamination in schools. Under AHERA, asbestos-containing material (ACM) is considered unsafe for children and its presence in schools is closely regulated. By defining ACM as any material containing one percent asbestos or greater the EPA restricted the use of products and materials with detectable amounts of asbestos, but allowed the continued use of products and materials in which asbestos was only a very minor ingredient (Perry 2004). These regulations are effective at controlling asbestos but only under certain conditions. For instance, they do not establish permissible general or ambient levels of asbestos in the atmosphere nor do they establish acceptable levels of asbestos in the soil or water (the U.S. Clean Water Act does establish asbestos limits for drinking

[20] It is generally accepted that the naked eye can see objects no smaller than 30-40 µm.

[21] The U.S. Environmental Protection Agency (EPA) regulations (AHERA, 1986) and the U.S. Occupational Safety and Health Act (OSHA, date) identify asbestos containing materials (ACM) as those that contain a minimum of one percent asbestos by weight. Materials that contain less than 1% by weight asbestos are non-regulated and thus may be assumed by the public to be safe to use.

water). Under these conditions, the determination as to an "acceptable" level of asbestos contamination in soil is therefore left to the EPA (Perry 2004; Lubenthal 2009).

This standard first came into effect in 1986 and according to Troast (2004, pers. comm., as referenced by Perry 2004) the limit of one percent asbestos by weight for ACM is a somewhat arbitrary level and was chosen because of technological constraints (i.e., polarized light microscopy (PLM) could not detect asbestos levels below this level). This position is corroborated by the Agency for Toxic Substances and Disease Registry (ATSDR), wherein it describes the one percent level as not a health-based standard, but representing the practical detection limit in the 1970s when OSHA regulations were created (ATSDR 2001).

This one percent definition of an asbestos containing material (ACM) has led to some confusion, at least in the United States. For example, the City of Cambridge, Massachusetts has determined that soil found to contain greater than one percent asbestos fibres by mass is "dangerous to human health" (City of Cambridge 1999). According to a U.S. EPA press release "as a point of reference, EPA considers soil samples with one percent or less asbestos to be an acceptable level" (EPA New England 2000 p. 1). In fact these statements are not consistent with the applications of these regulations nor are they supported by the relevant literature. Studies show that disturbing soils containing less than one percent amphibole asbestos can suspend fibres at unhealthy levels (ATSDR 2003). According to other U.S. EPA correspondence, clean-up thresholds should be established based on "background" levels, which may vary from rural to urban areas (Toland 2004 pers. Comm., 12 March).

Given the lack of knowledge as to what, if any, level of asbestos within soil or building material can be considered safe, it is important to determine how asbestos is currently identified within these media and how effective these methods are at actually determining the content of asbestos. A method that is relatively efficient (in both cost and time) and that does not require extensive technological resources or training is the most appropriate in the context this research. The method should allow for a large number of bulk soil and building material samples to be collected and analysed efficiently and cost effectively so that extensive areas of suspected environmental contamination can be assessed in a relatively short time period and without the dedication of large sums of money.

The objectives of this chapter are the following:

- Review existing methodologies for the assessment of environmental asbestos contamination for their applicability to the South African context;
- Determine if the visual (unaided) determination of asbestos in soil and building materials is accurate and sufficient to utilize in the Study Area (and for continued application by DME and possibly DEA);
- Determine if the preferred methodology of stereomicroscopy is accurate and sufficient to utilize in the Study Area as a screening-level measure of the presence or absence of environmental asbestos contamination of soil and building materials.

4.2. Methods and materials

A literature search for visual soil analysis procedures for asbestos yielded very few standards or accepted practices. Most jurisdictions rely upon some form of microscopic analysis of materials to determine the presence or absence of asbestos fibres of bulk samples with the tendency to use polarizing light microscopy (PLM). This research identified no published standards for a visual only assessment method that had been completely adopted by a regulatory authority. A number of laboratory methods are currently in use for soils analysis, but most of these have not been formally adopted by regulatory agencies. The following is a review of methods that rely (or partially rely) upon a visual assessment.

U.S. EPA Region 1 Method

The US EPA (Region 1) published a prototype method that involves using sieves, water solution and visual assessment followed by polarizing light microscopy (PLM) (USEPA Region 1, 1991). Samples are viewed through a stereomicroscope and those with suspected asbestos fibres are then analysed using PLM. This method is similar to that chosen for this research except that the EPA method uses sieves to separate larger particles from the sample matrix and then water is added to the sample matrix to float away organic debris and to wet the surface area of fibres for easier identification. These steps were not considered necessary for the samples analysed by this research for the following reasons.

1. The use of sieves required additional decontamination between each sample. Additionally, there was a concern that fibres could adhere to the larger particles and then be removed prior to identification. In order to ensure adequate size separation, some form of mechanical agitation is needed. This introduces the potential for the generation of airborne fibres. Much of the laboratory analysis was done without the use of a negative air exhaust hood and there was no HEPA (high efficiency particulate absorption) filtration available thus this method was considered too dangerous for the laboratory technician.

2. Most samples did not contain large amounts of organic material or debris. Wetting the samples caused the soil material to clump and what organic material was present would smear and stain the sample matrix and discolour the water. This made it difficult to identify the fibres under the microscope, especially in the darker coloured soils with organic matter and those soils with high clay/silt contents. Subsequent drying of the samples added time to the process.

ASTM E1368

ASTM International (2003) publishes a method for visual assessment of abatement projects. One of the stated objectives is to, "to verify if visible residue, dust or debris, or unremoved asbestos containing material are absent at the completion of removal and clean-up activities" (ASTM 2003, p. 3). This standard contains a brief description of a visual method to ascertain if clean-up of crawl spaces with dirt floors is adequate. The method involves a close visual examination of the surface with a bright light to observe any residual asbestos contamination. It is applicable to projects where the asbestos has been removed (such as pipe insulation) and a visual inspection is designed to identify debris (presumed to be asbestos) that remains after the abatement work is completed. The absence of visible material or suspected asbestos debris along with air monitoring is then used to verify a successful abatement project.

The ASTM standard is not directly applicable to this research in that the asbestos contamination within the Study Area is not the residue of a clean-up action nor is it the result (in most cases) of previously installed commercial asbestos products. Therefore it is unclear as to the whether the physical properties of the materials are consistent and thus the validation of this method is not commented upon by this research. However, the endorsement of the visual approach to identifying asbestos contamination does provide credibility and this research has adopted the recommended use of a bright light to illuminate the surface area to aid in visual identification.

Efforts at developing techniques to analyse asbestos in soil using polarized light microscopy (PLM), transmission electron microscopy (TEM) and scanning electron microscopy (SEM) have been made but there are no widely accepted methods or validation (Perry 2004). Soils are heterogeneous by nature and contain a wide variety of mineral types and sizes, organic matter, and in developed areas manmade artefacts. The ability to provide sample results that are reproducible and that can be considered representative of the entire matrix are required or, a method that takes these features into account is necessary. Additionally, existing counting methods (counting the number of fibres observed in a sample) are not applicable to soil samples as there is no congruence between the numbers of fibres observed in a soil sample versus the number that will appear in an air sample (Perry 2004). This is the result of the drastically different methods of sample preparation and the interference of other portions of the soil matrix. Some attempts have been made to calculate the amount of asbestos present in soil using mass percent however, "there is no direct relationship between mass estimates of asbestos concentrations and risk whereas fibre counts are a more useful metric." (GETF 2003, p.72). Also, according to Kauffer et al. (1996 as quoted by Perry 2004), measuring asbestos using mass percent is notoriously inaccurate. Lastly, it is difficult to know what level of asbestos in soil poses a similar health threat to a certain asbestos concentration in air because it is difficult to predict the fraction of asbestos fibres that will become airborne given the wide variety of conditions to which it may be exposed (Perry 2004).

The following laboratory methods are often used for soil analysis and were considered for this research. They are described below.

U.S. EPA Superfund Method

In an effort to overcome some of the limitations of soil heterogeneity and associated risk levels the USEPA developed the Superfund Method for the Determination of Releasable Asbestos in Soils and Bulk Materials (US EPA 1997), also sometimes referred to as the Berman Dust Generator Method. The method was developed to satisfy the needs of the Superfund Program, specifically,

- to provide results suitable for supporting risk assessment;
- to be applicable to the types of asbestos-containing materials commonly encountered at Superfund sites; and
- to facilitate reproducibility within and between laboratories that may offer the method commercially.
- An additional need is the consideration of developing a method that controls costs (EPA 1997 p. 2-1).

This method relies upon a rather elaborate field sampling and preparation process requiring well trained technicians, personal protective equipment (PPE), and equipment (such as riffle splitters, screens, sieves, etc). This quantitative laboratory method requires a complicated set-up of dust generator, elutriator and TEM analysis capabilities. It was developed to conduct site specific characterization of contaminants and is not a screening level approach.

Based on calculations presented as part of the feasibility study for this method (USEPA 1997), asbestos concentrations in soil or a bulk environmental matrix on the order of $3x10^7$ long asbestos s/g_{solid} (i.e. 30 million asbestos structures longer than 5 µm per gram of solid) or $5x10^8$ total asbestos s/g_{solid} (i.e. 0.5 billion total asbestos structures per gram of solid) may potentially pose a cancer risk exceeding 1×10^{-6}. This is based on conducting experiments designed to simulate the effects of vehicular traffic, agricultural tilling and natural weathering of asbestos contaminated soils and building materials (USEPA 1997 p. 2-2). However, this method has not been validated as of yet. While it holds merit for producing a more accurate assessment of the risks associated with exposure to environmental contamination of asbestos, efforts to validate the method are needed to determine its relationship to conditions likely to be encountered in the environment. It was not selected as the preferred method for this research due to the complexity of the sampling and laboratory methods, the expense of equipment and need for extensive training of field personnel. In addition, the field methods are inherently dusty and could lead to exposure of adjacent areas especially in the villages where samples were being collected. According to the method estimate each sample cost approximately R 7,000 to analyse (Berman and Crump 1999). As such, it is not appropriate to the South African context where potentially contaminated areas are extensive.

U.K. Method HSG 248 (formerly MDHS 77)

The U.K. Health and Safety Executive (HSE) Method HSG 248 (formerly MDHS 77) utilizes polarizing light microscopy. It is specified for bulk analysis of materials and is the required method per the South African Asbestos Regulations (South Africa Department of Labour 2001). This method is essentially the same as the US EPA Method 600-R-93-116 (1993) for bulk analysis as described below for PLM.

Polarized Light Microscopy (PLM)

PLM is the most widely accepted method for bulk analysis of building materials and insulation and has been widely adopted in the U.S., U.K., and South Africa regulations. The technique relies on optical microscopy where a sample is viewed using stereomicroscopy and those portions that are suspected of being asbestos are segregated for further analysis using PLM or a representative portion is also viewed under PLM to confirm the absence of asbestos. Particles of suspected asbestos are categorized based on fibre morphology, refractive index, colour and birefringence. A number of approaches have been adapted from existing methods for bulk analysis in the U.S. to utilize PLM for the detection of asbestos in soils, namely, the NIOSH 9002, EPA Method 600-R-93-116 and two EPA methods developed for Libby, Montana (SRC-Libby-01 [Revision 2] and SRC-Libby – 03 [Revision 1]).

In an effort to make these methods quantitative, or at least semi-quantitative, mass percent of asbestos is determined by visually estimating the fraction of the total material in a microscope field of view that is composed of asbestos and equating this to a mass percent or, estimating the mass percent by counting the number of asbestos structures present and relating the results to a standard curve. The visual approach is difficult, in particular when dealing with low asbestos concentrations (Brattin 2004). Estimates between analysts will vary and the assumption that the area fraction can be equated to a mass percent may be incorrect (Brattin 2004). The option of using a standard curve is predicated upon the basis that a curve is matched to the soil that is being analysed but few standardized curves have been developed. There are no curves that have been developed for the mining regions of South Africa.

However, PLM has advantages in that the techniques are not complicated, the equipment needed is minimal and the training of analysts is not time-consuming (the method is similar to standard mineralogical analysis), and overall the method is not expensive (less than R100/sample on average). However, in South Africa, there are few commercial laboratories that offer the laboratory analysis and few analysts who have been adequately trained for asbestos identification, and additionally, there is no national proficiency testing (such as in the U.S. or U.K.).

The results of PLM analysis can lead to false negatives (asbestos not being identified and reported) and the reproducibility of results is problematic due to the heterogeneity of samples and differences in analysts (WHO 1986; ATSDR 2003). However, a GETF report (2003) states that PLM can identify asbestos down to a concentration of one percent reliability and this method continues to be the industry standard with respect to bulk sample analysis.

State of California Air Resources Board (CARB) Method 435

The California Air Resources Board (CARB) Method 435, "Determination of Asbestos Content of Serpentine Aggregate" (1991) was developed to address the threat of environmental pollution from naturally occurring serpentine asbestos within aggregate storage piles, on conveyor belts, road surfaces, and parking lots. Parts of California contain natural chrysotile asbestos (serpentine mineral) outcrops. As such it is a potential contaminant in quarry operations and within materials used to build roads, parking lots and as common fill. The CARB method covers sampling protocols, frequency and analytical procedures. The microscopic analysis of suspected asbestos uses polarizing light microscopy with dispersion staining (technique described in PLM review). The method does allow for a stereomicroscopic analysis for all samples as an initial step and as the only step for those suspected of containing no asbestos. Three slides are prepared without dispersion staining and ten fields are viewed for each slide. If all fibres are non-asbestos, then no asbestos detected is reported including that the visual technique was used. If one fibre is determined to be asbestos, then the visual method is discontinued and the PLM method with point counting (quantitative analysis to determine the percent asbestos) is performed.

U.K HSE draft method

A combination of PLM and phase contrast optical microscopy (PCOM) was utilized by Davies et al. (1996) in research conducted on behalf of the U.K. Health and Safety Executive (HSE). They developed a quantitative method for analysing very small concentrations in loose aggregates and soils using PCM and PLM to determine mass percentages. According to their findings, while large variations are to be expected, accurate and precise results could be achieved for a wide range of concentrations down to 0.001 percent. Further field trials concluded the method to be reliable. The method has two stages with the initial sample being evaluated by stereomicroscopy for the absence or presence and approximate proportions of asbestos fibres. Next the suspected fibres are confirmed to be asbestos (by type) using PLM and dispersion staining protocols. If there is obvious asbestos contamination, then no further testing is done. However, if there is no or trace levels of asbestos detected, then an aliquot is mixed with distilled water, agitated, the drained through a membrane filter and analysed using PCOM at 100X to 500X. Point counting and sizing of the asbestos particles is completed and the mass percentages are calculated (Davies et al. 1996).

Transmission Electron Microscopy (TEM) and Scanning Electron Microscopy (SEM)

Perry (2004) also provides a review of electron microscopy methods for identifying asbestos in soil. TEM and SEM have both been used to quantify (mass percent and fibre counting) asbestos within soil. TEM and SEM have the advantage of being able to detect and confirm asbestos using electron diffraction (ED) and energy dispersive X-ray analysis (EDXA) and the very small fibres (respirable range) can easily be detected owing to the greater resolving power of these instruments over optical microscopy techniques such as PLM and PCOM. TEM and SEM routinely detect asbestos fibres to be present in samples that have been reported as NAD (no asbestos detected) using optical microscopy (Christensen et al. 2003). The disadvantages are the expense and complicated sample preparation process (both direct and in-direct) and the inability to reproduce results based on sample heterogeneity (a problem encountered by all soil analysis methods). This is magnified by the fact that only a small portion of the sample is actually analysed (Perry 2004). Still, SEM is used as a screening level tool with mass percentages estimated by the analysts and the assumptions that the samples are representative with even distribution of fibres throughout the sample. SEM preparations are less time consuming and require less training on the part of the microscopist. It also allows for a larger surface area to be scanned thus improving the reliability of the results reducing the potential for false negatives.

Within South Africa, facilities for the analysis of asbestos by TEM or SEM are extremely rare, limited to a few research universities and government departments. There are few technicians specifically trained and experienced at analysing asbestos. SEM and TEM were not considered as the primary method of sample analysis for this research due to the fact that there is limited capacity within South Africa to complete the requisite number of samples, the method is time consuming and expensive, and other methods, as described below, were considered more appropriate for this context. SEM and TEM were used to aid in the identification of asbestos in soils for comparison to the stereomicroscopy and PLM analysis.

4.2.1. Preferred method

This research collected 1 873 samples, of these 1 398 were visually assessed using the methodology described in 4.2.2. This method is likely to be more accurate than simply observing asbestos on the ground since it was completed in a more controlled and systematic manner. The 1 398 samples were subjected to a visual assessment and then a microscopic assessment (per the method described in Section 4.2.3). A total of 97 samples were further analysed by PLM by an outside independent laboratory (Margin of Error [MOE] of 8.06% at a 90% Confidence Level [CL]).

The use of a stereomicroscope as a screening level, qualitative examination of asbestos in bulk samples is a generally accepted and widely used method as the first step in the current USEPA and British HSE methodologies (Perry 2004). In general, these methods use a combination of a low magnification stereomicroscope for preliminary examination and estimation of the occurrence and percentage of fibrous components, followed by a detailed examination using a polarized light microscope of individual fibres teased out of the bulk sample (Stewart 1988; McCrone 1985). The method calls for bulk samples of building materials to be first examined with a low power binocular microscope with the following observations made:

1. Can fibres be detected?

2. Is the material homogeneous?

3. What types of fibres are present?

4. What is the approximate volume percent of suspected asbestos fibres?

5. Can individual fibres or fibre bundles be separated for more detailed analysis by polarizing light microscopy methods?

McCrone (1985) lists the four reasons for using stereomicroscopy:

a. The homogeneity of the sample can be judged

b. Fibres can be detected

c. Individual fibres can be tentatively identified

d. Individual fibres of each type can be removed for identification by PLM with dispersion staining.

According to Stewart (1988), the results of this method represent generally good reproducibility and good accuracy in assessing the volume percentage of an asbestos mineral in an insulating material and that accuracy is not affected by the material's homogeneity. However, with respect to soils, Brattin (2004) reports that it is difficult to estimate the area fraction for asbestos, especially at low concentrations and Perkins et al. (1994) reports problems with miss-identification and a tendency to overestimate the mass percent of asbestos.

The use of stereomicroscopy was chosen as the primary means of identifying the presence of asbestos within the samples collected as part of this research. The reasons are as follows:

1. The method is efficient in that a large number of samples can be analysed per day by a minimally trained microscopist.

2. The material and equipment needed is readily available within South Africa and does not require extensive training and are not expensive.

3. The method is reproducible (even if the results for soil may be somewhat variable) and has been incorporated into a number of standards previously adopted by regulatory agencies. It is considered an acceptable method for qualitative analysis of asbestos content and as a screening level assessment tool.

Disadvantages of this method are it does not have the same resolving power of PLM (≈400X) nor scanning/transmission electron microscopy (up to 30 000X) and therefore relies upon seeing larger fibre bundles as a surrogate for the presence of much smaller fibres. The concern for sample heterogeneity is only accounted for by collecting a much larger sample set from which to draw correlations.

A subset of the samples collected as part of this research was sent to an outside laboratory for PLM analysis using the USEPA method (600-R-93-116). This analysis was done to introduce an independent assessment of the samples in order to validate the stereomicroscopy analysis including confirming the type of asbestos present and the approximate percentages. Figure 4.1 is a diagram of the assessment protocol utilized in this research.

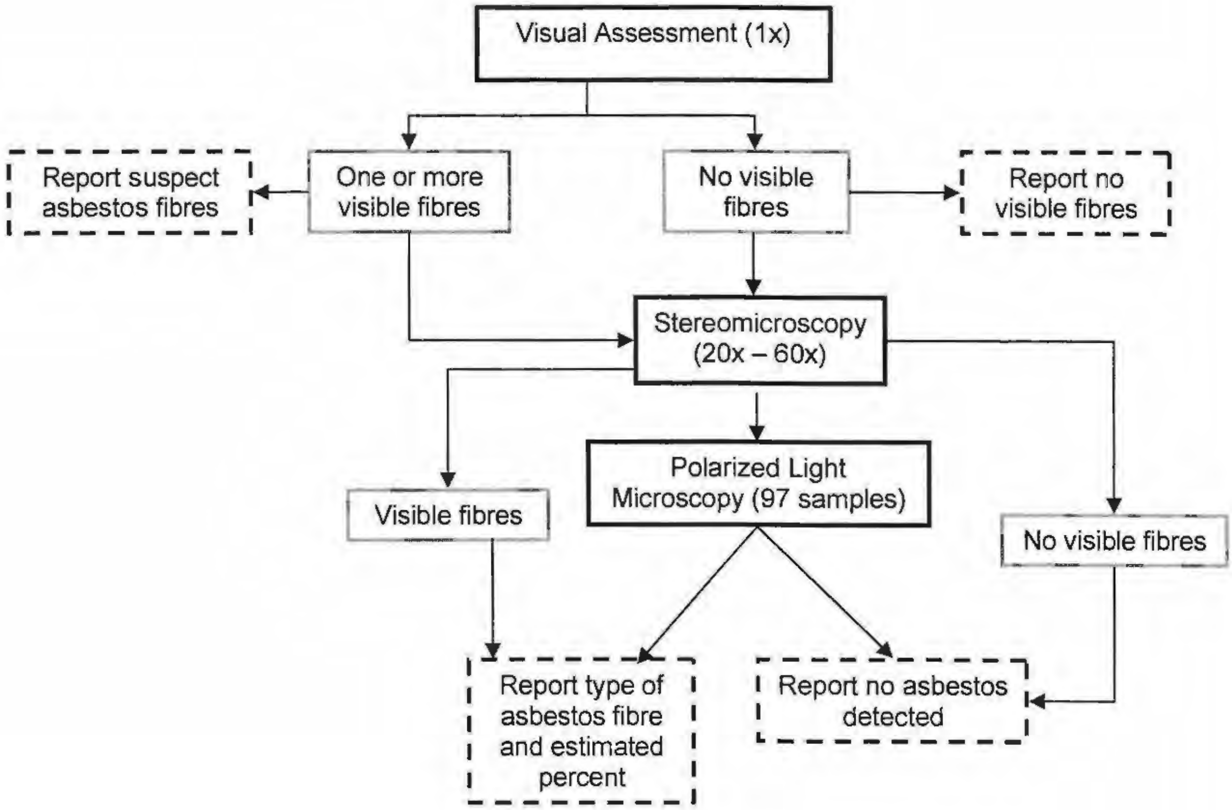


Figure 4.1: Diagram of the sample analysis protocol utilized in this research.

The following is a brief description of the sample analysis protocol developed for this research.

4.2.2. Bulk sample laboratory assessment

Field samples were shipped or carried back to the researcher's office from the field. Shipped samples maintained a written chain-of-custody. Each sample container was checked for integrity against the appropriate Data Form and that the container had not leaked or ruptured. The sample container was checked to ensure it was free of soil or dust on its exterior. If present, it was wet wiped clean and air dried prior to further handling. If material was found in the bottom of the sample box, then the source of the debris was discovered (for example if a bag had ruptured). Each sample was checked to ensure it was properly labelled with the sample number, date, sampler's initials and material type. This information was then checked against the sample Data Form to determine that the information matched. If the sample container information did not correspond to the Data Form and the cause of the discrepancy could not be readily rectified, the sample was excluded from further analysis. The following procedure for visual assessment was utilised.

1. Place the sample flat on a clear white background (clean copy paper or poster board).

2. Aim a bright lamp (minimum 40 watt) towards the sample.

3. Spread the sample material out to a thin even layer against the white background.

4. Visually scan across the sample looking for fibrous structures (either alone, or as part of a structure).

5. Identify fibrous structures that are dull blue, brownish, or off white. Use reference samples if needed for comparison purposes.

6. Using a probe or forceps apply pressure to the fibrous structures and observe its habit for splitting. Fibres that break horizontally are not likely to be asbestos. Those that break into smaller fibres longitudinally, and that display splayed ends, are more likely to be asbestos.

7. Note whether suspect fibres were reported as being visible on the Data Form or Sample Log Sheet.

Material that was fibrous, (greater than 3:1 aspect) and had the physical characteristics of asbestos (primarily shape and colour) was noted as, "visible fibres present" and recorded on the database and sample data sheet. This visual assessment included fibrous rock fragments. This crude form of initial assessment was conducted in order to test the validity of using a visual assessment technique for the identification of asbestos fibres in soil and building material. Samples with no visible fibres were not considered free of asbestos contamination. Each sample was then subjected to stereomicroscopy analysis as described below.

4.2.3. Stereomicroscopy analysis

The objective of the stereomicroscopy analysis was to verify if the absence or presence of suspected asbestos fibres in a given sample could be ascertained and to quantify the relative percent of asbestos fibres compared to the total sample material (as an approximation of mass percent). This more definitive analysis was also used to validate the results of the visual assessment described above by either confirming the presence or the absence of suspected asbestos fibres. The following procedure for stereomicroscopy analysis was utilized by the author previously trained in asbestos microscopy.

1. Each sample container was carefully opened to avoid generating dust. Using a plastic spoon, approximately 0.5 gram of soil or an equivalent portion of building material was removed and placed in a clean, clear, plastic Petri dish.

2. For soils, the dish was covered and gently agitated to spread the sample across the bottom of the dish to an even layer. Building material specimens were not agitated. The dish was then placed under the microscope and the cover removed.

3. The sample was scanned looking for fibrous structures (either alone, or as part of a structure) at 20x to 60x resolution and by racking the lens vertically to focus on the depth of larger specimens. Using fine point probes suspected fibre bundles and/or fibrous fragments were teased apart by gently applying pressure to test for longitudinal splitting of the bundles. For building material samples, which were typically more angular and blocky in shape, the face of the sample was analysed to identify the existence of fibres protruding from the structure and along the edges. The external light was focused to the areas being optically scanned.

4. Fibres were identified based on their colour (typically dull blue, brownish, or off white). Reference samples provided by the Nelson Mandela Metropolitan University were used to compare to the target sample. A standard reference chart (modified from Terry and Chilingar 1955) was used to estimate the relevant mass percentage of suspected asbestos fibres to the remaining material. Friability for building materials was then noted and the data were recorded on the Sample Log Sheet.

5. All samples received at least one stereomicroscopy analysis. Ten percent of the samples received a second prep from the sample container wherein the procedure was repeated to confirm the initial reading. If either of the two preps contained at least one fibre or fibrous fragment, the results were recorded on the Sample Log Sheet with the approximate volume percentage estimate and asbestos type. The material was then returned to its original sample container.

For the purposes of this assessment methodology, the asbestos concentrations are reported as NAD (no asbestos detected), Trace (both defined below), 1-3 percent, or greater than 3 percent.

NAD: (No asbestos detected), This did not mean that asbestos was not present in some small amount, but that the level of detection employed in the analysis could not ascertain the presence of regulated asbestos fibres, fibre bundles or fibrous fragments.

Trace: Amounts of asbestos less than 1 percent by area coverage on a given preparation are considered trace. This may equal one or more fibres, fibre bundles, or fibrous fragments in a given sample preparation.

The definition of asbestos used above should not be confused with the definition of a "regulated asbestos fibre" per the South African OHSA Asbestos Regulations (South Africa Department of Labour 2001). The definition provided by OHSA relates to occupational exposures and does not account for the variety and condition of asbestos structures encountered in the environment surrounding the former mining areas. For instance, fibrous fragments do not meet the definition of a regulated asbestos fibre, but upon pressure to the fibrous portion of the fragment, fibres can be released. It is for this reason that the term asbestos, as applied to this research, includes regulated asbestos fibres as well as those structures with the potential to release regulated asbestos fibres into the environment.

4.2.4. Scanning Electron Microscopy

In order to assess the validity of these methods against one of a higher resolving power, three soil samples were chosen for additional analysis by the author using scanning electron microscopy (SEM). SEM methods for soil analysis have been developed by the U.S. EPA for analysis of the soil contamination in the vicinity of the Libby, Montana Superfund Site (Perry 2004). The method utilized by the author is a qualitative method developed to assess the validity of the less refined optical microscopy methods employed and does not report quantifiable results.

The Rhodes University Microscopy Lab provided the author the use of their Joel JSM 840 – 10.0 kv SEM to visually assess a small quantity of each of three samples. The author selected one sample (GMNPS-2) that had been found to contain no asbestos (NAD) by stereomicroscopy, one sample of soil (S4) that had been found to contain no asbestos (NAD) by stereomicroscopy and PLM analysis (by Omni Lab), and one sample (BTS-LH5) that had been found to contain trace amounts of asbestos by stereomicroscopy.

1. The original sample containers were transported to the SEM lab for analysis by the author. Each sample container was opened and a small aliquot of the sample (approximately 0.1 milligram) was randomly selected from the container.

2. The sample was mounted with sticky tape to a brass stub and placed in the SEM for analysis.

3. The entire surface area of each sample was scanned at a magnification of 500X and where suspect fibres were encountered, the magnification was increased from 500X to 3,300X to more accurately observe and measure the individual fibre(s).

4.2.5. Quality control

In order to avoid cross-contamination between samples, the Petri dish and all instruments used during laboratory analysis were washed and triple rinsed with tap water between each sample and dried with a clean paper towel. Using a brightly coloured paper towel left fibre residue that was easy to recognise as non-asbestos and furthermore, cellulose fibres are readily distinguishable from mineral fibres under a microscope. The cleaned Petri dish and instruments were checked after every 10 samples under the microscope to confirm the absence of sample residue.

In the case of the Rhodes University (RU) Microscopy Lab, no highly efficient particulate absorbing (HEPA) exhaust hood was available. The technician wore a half-face air purifying respirator during sample analysis. The sample prep area was wiped clean before and after initiating sample work. A HEPA fitted exhaust hood was utilized at the Nelson Mandela Metropolitan University laboratory for those samples analysed at that location. Disposal of very small amounts of potential asbestos waste (residue in the Petri dish) down the sink was determined to be an acceptable practice as the material was adequately removed from human exposure via its disposal through the waste water treatment system and ultimate discharge to a nearby stream. In addition, many of the water conveyance pipes in the vicinity of the Lab and within the municipality were confirmed by the author and independent testing to contain 30 percent asbestos fibres.

All samples transported included a standard chain-of-custody to track the samples from their point of origin to their final destination. The chain-of-custody was maintained throughout the project for all samples. The RU laboratory ceiling was also tested to confirm it contained no asbestos (due to suspicious material). The selection of five percent of the samples for redundant laboratory analysis was completed to confirm the validity of the methodologies employed in this project. Given the inherent dissimilarities in the sample analysis procedure, a certain tolerance for reporting differences was expected (Perry 2004; Brattin 2004; McCrone 1985; GETF 2003).

4.3. Results

4.3.1. Results of visual versus microscopic analysis

Based on a comparison of the visual assessment versus the use of a stereomicroscope at a resolution of 20X to 60X, asbestos contamination was missed (false negatives) in 19 percent (n = 261) of the samples using only the visual method as confirmed using stereomicroscopy. False positives (misidentifying asbestos fibres that were not present) occurred in 44 samples (3%). The total number of incorrectly identified samples was 305 (22%). Of these incorrectly identified samples, the largest percentage resulted from false negatives of samples determined by stereomicroscopy to contain trace levels of asbestos (n

= 225), or 86 percent of all false negatives. A congruent observation was reached on 1 093 (78%) of the samples identified (see Figure 4.2).

Soils were the largest subgroup of samples to be subjected to this test (Figure 4.2). A total of 933 soil samples were analysed by both visual and microscopy analysis. False negatives were reported in 216 (23%) of the samples, 94 percent of these being on soils identified as having trace levels of fibres. False positives were only reported in 34 (4%) of the samples, giving a total percentage false reading of 27 percent. Building materials samples were also subjected to this test. A total of 465 building material samples were analysed by both visual and microscopy analysis. False negatives were reported in 10% of the samples with a roughly equal split between samples determined to have trace levels versus those with greater than trace levels of contamination. False positives were reported in 2% of the samples (n=10) giving a total percentage false readings of 12% (n=55). Congruence between the visual and microscopy analysis overall for the building materials was 88 percent (n=410) considerably better than for soils analysis (see Table 4.1).

Table 4.1: Results for unaided visual examination versus microscopic analysis

	ALL SAMPLES	BUILDING MATERIALS	SOIL
Congruent Analysis	1093	410	683
False Negatives (Trace)	225	22	203
False Negatives (>Trace)	36	23	13
False Positives	44	10	34

In order to rule out bias and error on the part of the primary lab technician with respect to the visual analysis, a total of 39 samples were sent to an outside asbestos analyst for back-up analysis using a similar visual method (margin of error 13% at 90% confidence level). He viewed 23 soil and 16 building material samples using a protocol modelled from the author's with only minor modifications[22]. The examination results at 1X+ agreed with the author's 17 of 23 times (74%) for soil and 10 of 14 times (71%) for building materials (2 were undetermined). This indicates that there is a significant variation between observers using two very similar methods. This may be accounted for by differences in the visual acuity of the observer, the heterogeneity of the sample matrix, the use of a magnifying lens, and removing the sample from its original container (which tends to improve the visual clarity of the material). Comparing the outside analyst's further examination of the same samples under a stereomicroscope, agreement was reached 17 of 23 times (74%) for soil and 9 of 14 times (64%) for building material (2 undetermined). There were six false negatives for the soil samples (26%) and five for the building materials (36%) with no false positives for either. The outside analyst had an overall accuracy (visual versus stereomicroscopy) rate of 67% (with 2 undetermined) as compared to 78% by the primary analyst (author).

4.3.2. Polarizing Light Microscopy (by Outside Laboratory)

In an effort to further test this finding and to compare the results of the visual assessment to a more definitive method (polarizing light microscopy with dispersion staining), the author randomly selected 97 samples (7.1%) from the total set of visually assessed samples for confirmatory testing by an outside independent laboratory. The independent laboratory (Omni Labs, USA) is accredited under the United States NVLAP (National Voluntary Laboratory Accreditation Program) certification process. Samples were analysed to determine the positive identification of asbestos by type utilizing the methods prescribed by the U.S. Environmental Protection Agency (Improved Method EPA 600/R-93/116, 1993). This PLM method utilizes a combination of stereomicroscopy at lower magnifications and PLM at higher magnifications. The dispersion staining is used to more accurately determine the type of asbestos fibres present in the sample and minimize the reporting of other fibre types that may be similar in appearance. The results indicate only a 57% correlation (n=55) on the ability to identify asbestos

[22] The examination was performed in a HEPA-filtered exhaust hood with samples taken from their original container and placed in a pre-cleaned plastic tray. An illuminated magnifying lens was used (magnification unknown) to aid in the visual assessment. The stereomicroscope is a Graf-Apsco Model 400 with 15x and 30x magnification – only the 15x setting was used for the examination.

fibres using a visual assessment method completed by the author versus the more sensitive polarizing light microscopy method employed by Omni Labs. All errors were attributed to false negatives (n=42) with 79% of these being asbestos found by Omni at trace levels (n= 33), the remaining being at greater than trace (n=9) and no false positives.

This result is almost double the rate of misidentification by stereomicroscopy alone. This difference is likely to be the result of the greater sensitivity of PLM versus stereomicroscopy, differences in skill and training levels between the independent lab technician and the author, and the inherent heterogeneity of the samples. There was also a bias to under report the mass percentage of samples between the stereomicroscopic analysis and the PLM, in particular, levels reported as trace by stereomicroscopy were most frequently reported as 1-3% by PLM analysis. Again, this difference is likely due to variances between analysts and the greater resolving power of PLM analysis (up to 400X). However, over reporting of mass estimates is a persistent problem based on proficiency testing of labs in the U.S. (Perkins et al. 1994). Figure 4.2 is a photograph of a crocidolite fibre bundle collected from within the Study Area viewed under a stereomicroscope.

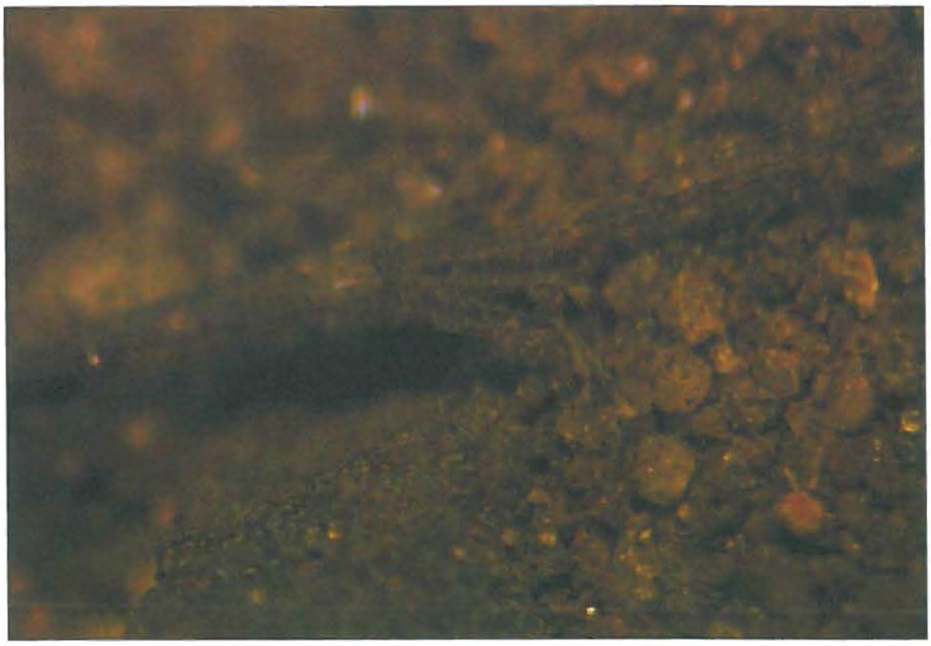


Figure 4.2: Image of crocidolite fibre bundle in soil from within the Study Area (credit: Omni Labs, USA)

4.3.3. SEM sample analysis

Three samples were selected for analysis by the author using SEM (per the method described in Section 4.2.5). The results indicated that sample number GMNPS-2 identified as NAD by stereomicroscopy contained two possible fibres but the results were not conclusive. Sample number S4 contained four suspected asbestos fibres, 10-12 μm in length and 2 μm wide (at 1,000X), 2 fibres of 20-30 μm in length by 1 μm wide (at 900X) and one fibre 90 μm in length by 2 μm wide (at 1,000X). This finding refuted the initial stereomicroscopy assessment by the author and the subsequent PLM examination by Omni Labs which indicated NAD. Sample number BTS-LH5 (identified as Trace – Crocidolite) contained five fibres ranging from 12-40 μm in length and 0.3 to 3 μm in width (at magnifications of 500X to 3,300X) confirming the stereomicroscopic analysis.

4.3.4. Asbestos fragment analysis

The inclusion of fibrous rock fragments in the definition of asbestos for this research is supported in that upon mechanical abrasion or pressure, the fibrous portions of the fragment can be dislodged leading to individual fibre bundles and fibrils within the biologically active size range being released from the fragment. These respirable range fibres are much more likely to become airborne as a result of agitation and therefore these specimens should be considered in the determination of risk for exposure. Fibrous rock fragments, with respect to this assessment, are those that meet the overall aspect ratio of 3:1, regardless of width and length or which demonstrate the ability to release thinner fibres upon pressure or agitation. "Cleavage fragments and amphibole asbestos fibres have fundamentally different properties and these differences are biologically relevant. Indeed, the toxicity of respirable cleavage fragments is so much less than that of fibrous amphiboles that by any reasonable measure they are not biologically harmful" (Ilgren 2004 pg 1). The major difference between Ilgren's definition and the author's may be in the use of the term "asbestiform." This study has included cleavage and other rock fragments that are or have an asbestiform capacity in that they tend to break longitudinally along cleavage planes and thus they essentially will meet the definition of a fibre if sufficient pressure or agitation is applied to the structure over a period of time (either from natural or anthropogenic sources).

To demonstrate this relationship between large specimens of asbestiform rock fragments and their capacity to degrade into thinner fibre bundles using minimal manipulation, a single specimen of Banded Ironstone was collected from the Ncweng Primary School site by the author and forwarded to MVA Scientific Consultants in the U.S. for microscopic analysis. Specimens of Banded Ironstone similar to this, in a variety of sizes, are prevalent in the environment of the former amphibole asbestos mining regions of South Africa and are routinely subjected to natural abrasion and mechanical degradation from humans. Through a series of microscopic analysis with increasing magnification of the fibrous portion of the specimen, it is clearly demonstrated that from the initial large section of Banded Ironstone, numerous thin fibrils, meeting the biologically active aspect criteria can be produced with minimal manipulation (see Figures 4.4 through 4.11). All fibres represented in the following micrographs were teased from the large fragment in Figure 4.4.

This occurrence was repeated on a regular basis during the sample analysis wherein large fibrous fragments (that do not meet the definition of an asbestos fibre) routinely disintegrated upon the application of very minimal pressure or agitation (as could be expected to occur in areas accessible to people or animals). These fragments ranged in size from less than 1 millimetre to several millimetres in length and/or width. This circumstance supports the inclusion of fibrous rock fragments in the definition of asbestos contamination with respect to this research and calls into questions the validity of excluding these structures from other common laboratory methods.

Figure 4.3: Sample of Banded Ironstone collected from Ncweng Primary School site in the Northern Cape – approximately 6.5 cm in length (Source of Photo: MVA Scientific 2004).

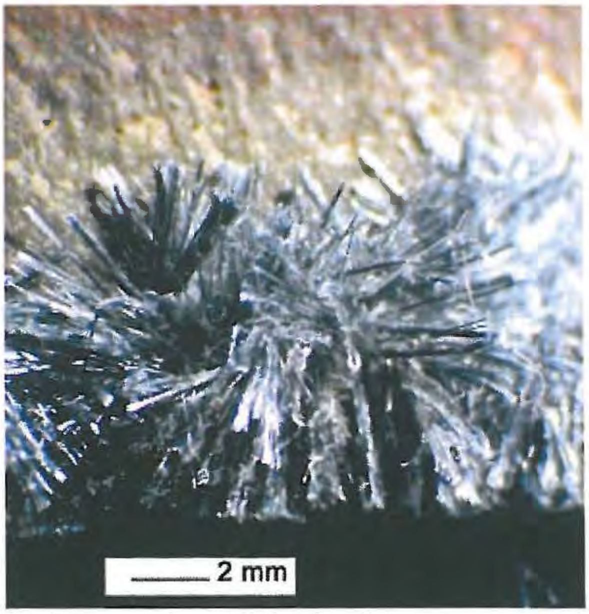


Figure 4.4: Close-up image of fibre seam within the Banded Ironstone (Source of Photo: MVA Scientific 2004).

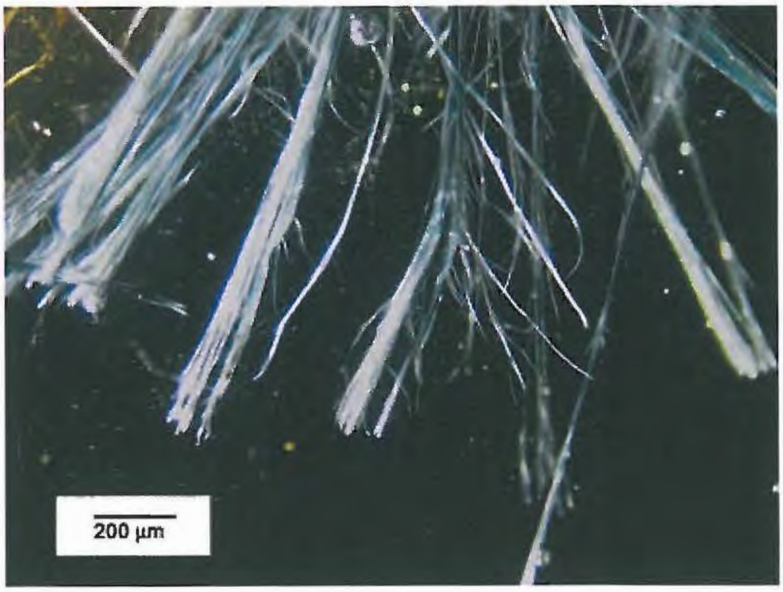


Figure 4.5: Light microscope image (reflected light) of crocidolite fibres (Source of Photo: MVA Scientific 2004).

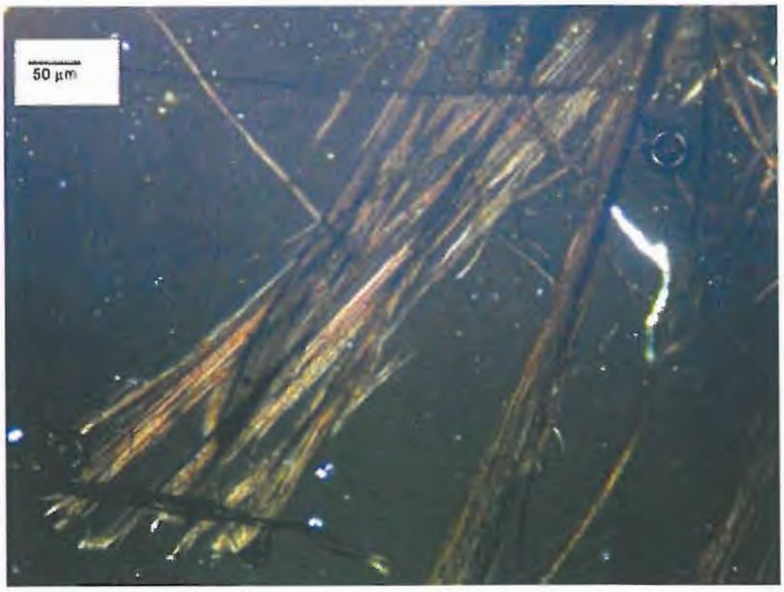


Figure 4.6: Polarized light microscope image (crossed polars) of crocidolite fibres (Source of Photo: MVA Scientific 2004).

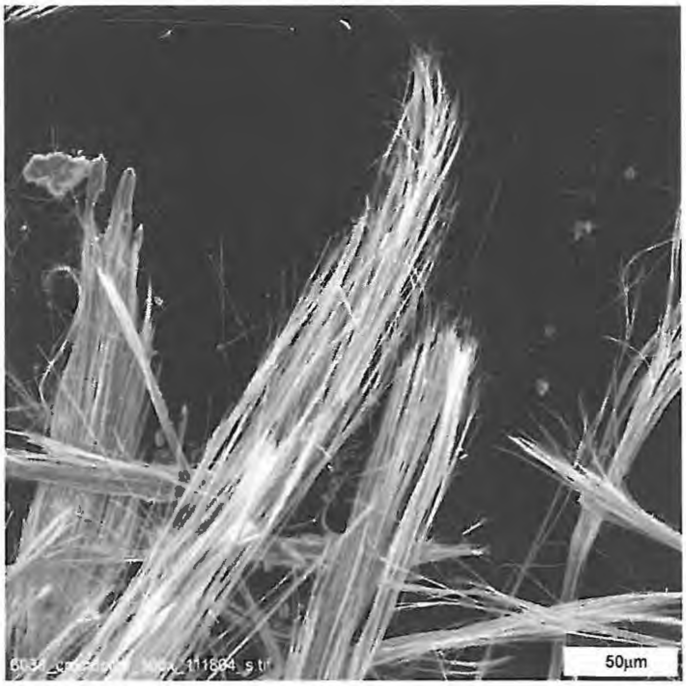


Figure 4.7: Scanning Electron Microscope (SEM) image of crocidolite fibres (Source of Photo: MVA Scientific 2004). Note the numerous very thin fibres dislodged from the larger bundles.

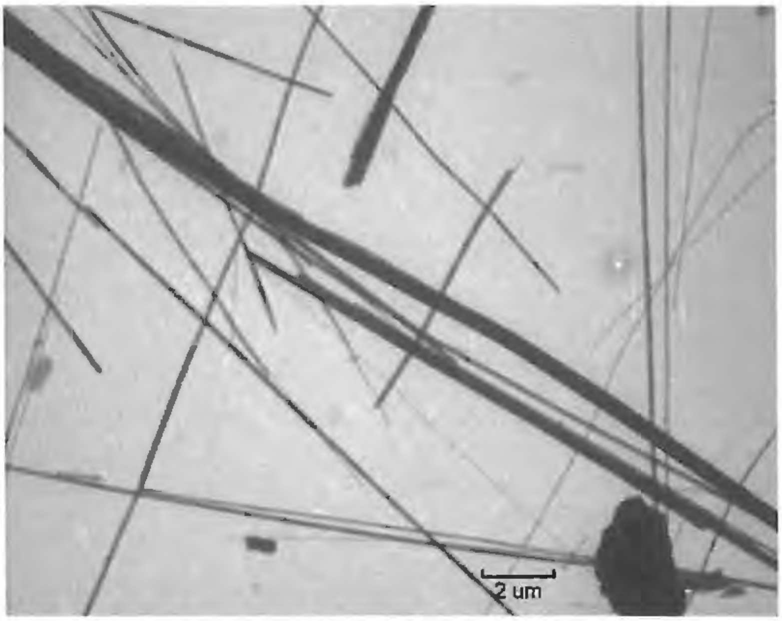


Figure 4.8: Transmission Electron Microscope (TEM) image of crocidolite fibres – note numerous thin fibres of a respirable and biologically active range separated from the fibre bundle (Source of Photo: MVA Scientific 2004).

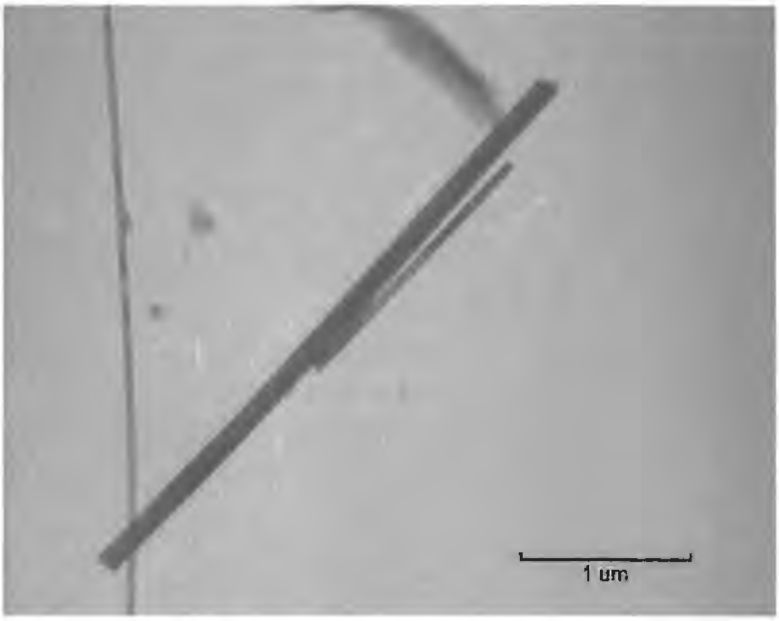


Figure 4.9: Transmission Electron Microscope (TEM) image of crocidolite fibres – note the thin crocidolite fibre on the left is less than 0.1 µm in width (Source of Photo: MVA Scientific 2004).

These series of micrographs clearly demonstrate the capacity of a large specimen of Banded Ironstone, which is ubiquitous in the environment surrounding the former amphibole mining regions of South Africa, to degrade into biologically relevant fibrils. It also substantiates the necessity to consider fibrous asbestos fragments, as defined in this assessment, within the classification of an environmental contaminant and as being potentially deleterious to public health.

4.4. Discussion

This chapter deals with one of the primary objectives of this research, the determination of the validity of using a visual assessment method for the identification of environmental contamination from asbestos in the former mining regions of South Africa. In addition, it has briefly reviewed the options available for asbestos sample analysis. The bias in the selection of methods to be used in this research has been for low cost techniques that are readily available within South Africa or where skills transfer could be affected. The preferred methods have been reviewed and summarized, including their relative strengths and weaknesses. This issue is important in that asbestos mining has occurred and continues to occur in numerous countries throughout the world, many of which are lesser developed with ineffectual environmental management or health and safety institutions. Several studies and numerous anecdotal accounts indicate the former and current mining areas of these countries are contaminated with asbestos waste (see Chapter 1). A method to quickly, cheaply and accurately assess the extent and severity of contamination is needed in order to identify those areas most likely to contribute to asbestos exposures to the local populations.

The validity of using a visual assessment has been compared to the preferred method of stereomicroscopy and found to be significantly flawed and is thus not supported. The visual assessment was found to be an inaccurate method of assessment with an incorrect identification in 22 percent of the samples (n=305). As might be expected, those samples with low levels of contamination (less than 1 percent) represented the largest number as false negatives. There was also poor congruence between two separate analysts using the visual assessment method with agreement reached on only 73 percent of the samples. The differences between analysts and methods (visual versus stereomicroscopy) are significant (27% and 22% respectively).

Given the propensity for the visual assessment to miss fibres present in both soil and building materials (false negatives) it is clear that visual assessment alone is not a reliable indicator for the presence of asbestos fibres, particularly at low levels of contamination (less than 1%). When compared to stereomicroscopy analysis, visual assessment of bulk building material samples was more reliable for determining the presence of asbestos (accuracy of 88%) compared to soil samples (accuracy of 73%). Comparing the visual assessment method against the PLM method (as completed by the outside laboratory), indicated the visual method had an accuracy of only 57%. False positives, on the other hand, were relatively rare with all three methods (visual, stereomicroscopy and PLM) yielding consistent results. The largest disparity occurred between the author's visual versus stereomicroscopy analysis with 3 percent of the sample set recorded as false positives.

The accuracy of PLM analysis has been assessed through round-robin test results conducted for the US EPA as part of the National Voluntary Laboratory

Accreditation Program (NVLAP), (Perkins et al. 1994[23]). Under this multi-year research as many as 17 percent of the participating laboratories failed to detect asbestos in a given sample and overestimation of the percent of asbestos was common regardless of technique (area estimating or point counting). However, at moderate levels of contamination (1.7%), false negatives only occurred in 10% of the samples. Over-estimation of the percent of asbestos increased as the sample concentrations decreased. Additionally, analyst bias (due to a lack of calibration and/or incorrect application of method) was common (Perkins et al. 1994).

Comparing the stereomicroscopy/PLM results to the SEM analysis (on three samples) also yielded a poor correlation. Fibres were detected in soil that where undetected by stereomicroscopy and PLM analysis on one and possibly two samples. The third sample was confirmed by SEM. This method was problematic in that the range of coarse material that sticks to the coated stub then scanned by the SEM is highly variable and the resolution is not always sufficient to make a determination. Using a sieve to remove coarse material prior to analysis was considered. However previous analysis has shown that fibres will occasionally adhere to the coarse fragments and are therefore lost when sieved out of the sample. It is also interesting to note the absence of short fibres (<5 um in length). These would be expected in a randomized sampling of asbestos. All of the fibres identified by SEM were within the size class considered biologically active. Assuming the sample (S4) was representative the identified trace levels of asbestos should equate to approximately 50 000 fibres/gram. This is well short of the estimated 3 000 000 fibres/gram considered an unacceptable risk per the U.S. EPA (Berman and Crump 1999). Despite this inconsistency, these trace levels (identified per stereomicroscopy) of contamination once disturbed can entrain fibres into the atmosphere and should be considered dangerous from a human health risk assessment perspective.

4.5. Conclusions

The visual assessment of asbestos contamination surrounding the former asbestos mining regions of South Africa may be sufficient to detect areas grossly

[23] Samples were of building materials, not soils.

contaminated where soil and building concentrations are greater than one percent. This was demonstrated by the low number of false positives between the visual and stereomicroscopy analysis. This method is useful as long as the constraints of accuracy are clearly understood by the user. However the vast majority of areas found to be contaminated are represented by levels less than one percent (trace) yet these areas, when disturbed are still capable of inducing airborne concentrations of asbestos that exceed acceptable levels. Therefore, the absence of visual contamination is not indicative of a lack of contamination or of a level that is sufficiently protective of human health, especially where it is within close proximity to settlements. Additionally, given the resource constraints in South Africa, and likely in many other developing nations, the ability to quickly screen for areas grossly contaminated by asbestos is needed and thus some form of visual assessment is likely to be used as at least a "first pass" at locating areas suspected of environmental contamination. If the contamination is visible to the naked eye than it is present in quantities that should cause concern for public health.

Of the varying methods employed by this research, all are problematic, in particular with respect to soils analysis at relatively low levels of contamination. Given the heterogeneity of soils, the results of all forms of optical microscopic methods of detecting asbestos are variable and it is difficult relating the results of the analysis to a corresponding level of risk however this issue will be more fully addressed in Chapter 7. Yet the results presented by this research are not inconsistent with other published studies (for example Perkins et al. 1994 and Perry 2004) and the methods utilized are supported in the literature and by present industry standards. Overall, stereomicroscopy is a valid form of identification of asbestos contamination in soils and building materials as a non-quantitative screening method. However, the results should not be used as the sole determinant in defining risk of exposure as there is a potential to miss fibre concentrations at trace levels.

Problems with this method may arise from the heterogeneity of soil samples, bias of laboratory analysts and the inability to detect soil contamination at low levels of contamination. Methods recommended to overcome these constraints are:

- adequate training and calibration of analysts,
- analysing a greater number of samples per site and greater number of aliquots per sample in order to produce more representative results and reduce the incidence of false negatives leading to an improper decision regarding risk,
- random selection of an adequate number of samples for confirmation by PLM or potentially SEM to correlate stereomicroscopy results, and/or
- application of the UK HSE Draft Method (Davies et al. 1996) on all samples identified as NAD using the preferred method.

Using the preferred methodology as developed for this research, the results of all samples analysed are presented per land use and community in Chapter five. These results are then used to estimate the total extent of environmental asbestos contamination with the Study Area based on this screening-level assessment.

CHAPTER 5

5. RESULTS OF SCREENING-LEVEL COMMUNITY SURVEYS FOR ENVIRONMETNAL ASBESTOS CONTAMINATION

My dad used to work at Koegas. He suffered a lot before he died, and that makes me sad. My mother died from the same asbestos dust. Maybe my sister will also die from it. These things happen...[24]

5.1. Introduction

Chapter three described the process and results of the community selection and the methodology used to select the land uses and individual sites for surveys of environmental asbestos contamination. Chapter four described the review and validation of possible methodologies using an increasingly refined level of detail, to assess soil and building material samples for asbestos contamination. This chapter discusses the media and community specific results and the relevance for the risk assessment input variables (discussed in Chapter 6).

There are very few assessments of environmental asbestos contamination for large geographic areas from which to draw reference. However, estimates of contaminated building stock based on in-place material have been completed in the past (see Section 3.5.1). Follow-up surveys in Libby, Montana have estimated the total in that community that will require remediation is approximately 47% (± 1 400 out of 3 000), (EPA 2008b). Other studies reviewed as part of this research include estimates of housing stock in the United States (USEPA 1988), Australia (Government of Australia 2008), and South Africa (Felix 1997; REDCO 2007). These surveys used varying methods of investigation and are not directly comparable but do give an indication of the potential for contaminated homes to exist in other parts of the world and in South Africa.

This research focuses on the results of community surveys designed to provide a screening- level assessment of environmental asbestos contamination. These surveys are ultimately designed to provide not only a more accurate understanding of the extent and severity of contamination but also to provide input into the

[24] Adam Oor, bor 12/05/34-died 20/09/99 as quoted by Du Plessis, Hein. Reprinted with permission.

exposure scenarios for the resident population. As such, a number of factors had to be considered in the process. These included the media specific contamination results (soil and building materials), condition of the contaminated media, its accessibility and the land uses of the contaminated areas. The U.S. EPA (1985, 1988) and Chesson et al. (1990) have documented that asbestos containing building material (ACBM) that is friable, in poor condition or frequently disturbed can lead to airborne concentrations of asbestos fibres. Additionally, soil that is contaminated with asbestos fibres can also lead to airborne concentrations and therefore where it is in close proximity to occupied dwellings, the prudent assumption is that exposures may be occurring on a regular basis. These exposures may occur on an almost continual basis for residents, including the elderly, children and home-based workers. For these reasons, it was considered important in this research to concentrate the screening-level surveys on land uses that represent a significant proportion of potential exposure periods.

Residential land uses (primarily single family homes on individual stands) represent the largest proportion of individual sites (n=259) and overall number of samples collected. In particular, those locations suspected of containing asbestos building materials or contaminated soils in close-proximity to previous mining or mine dump locations (see description of selection methodology provided in Chapter 3) were selected for sampling. Residences represent the most continual and long-term exposure potential for residents. Schools were the second most assessed land use (by number of sites surveyed [n=45]). Schools are a primary concern for exposure to asbestos for reasons related to childhood exposure and also for potential exposures to workers (teachers, administrators and custodial staffs). The U.S. EPA in a 1984 survey estimated that 35 percent of the public schools in the U.S. contain friable asbestos containing building materials (USEPA 1984). Construction methods, materials and the types of asbestos contamination found in the U.S. versus those encountered in the Study Area are considerably different with South African schools, in particular primary schools, being constructed of much less durable materials.

The third most common land use assessed by this research within the Study Area was roads. Roads and local streets within communities were assessed as part of the community survey with a total of 29 individual sites sampled. Twenty-one of the twenty-three roads sampled in the Northern Cape were dirt surfaced. Locations were also selected within specific communities (Ga-Mopedi, Heuningvlei, Magobing, Seodin, Sloja and Vergenoeg) to determine their condition and potential for generating dust in proximity to homes and gardens. The remaining land surveyed is summarized in Section 5.6 of this Chapter.

This research represents sampling of building stock and the physical environment where asbestos contamination was suspected based on the methodology and results described in Chapter 3. It is therefore not a random survey of locations within these communities. The percentages of contamination that are identified may therefore not be representative of the entire community nor will they represent communities within the region where there is less evidence of contamination. The results of the targeted community surveys could not be extrapolated to the non-surveyed segments of the communities, or other communities in the remaining provinces. This restriction in the results was addressed by conducting a more detailed (house to house) survey in one community determined to be representative of the Study Area. The results and comparisons between the targeted surveys and the detailed community survey are discussed in Section 5.10 of this chapter. The overall number of samples collected and analysed and the geographic scope of the surveys are significant. As a result, the potential exposures from asbestos pollution to the inhabitants should be a major community health concern. Results are reported per land use classification and per community.

The major objectives of this chapter are:

- Report the results of the screening-level surveys completed within each of the Moderate and High Risk communities identified in Chapter 3 per land uses surveyed and per sample media (soil or building materials);
- Report the results of a detailed survey within one representative community (Ga-Mopedi) within the Study Area; and
- Assess for trends in the data that can be used to extrapolate to communities beyond the limits of the Study Area.

5.2. Methods and materials

Chapter three described the methodology for identification of communities for screening-level surveys and for the selection of individual sites within each community for sample collection. It was realized that due to the large number of communities (36) to be surveyed and their overall geographic range (estimated at 21 000 homes over a 500 kilometre north to south distance) it would not be possible to sample all locations or even all suspected sites of contamination at a sample density sufficient to characterise the extent and severity of contamination. It was therefore determined to target those locations within each community that were representative of those sites suspected of being contaminated. At each location to be sampled the following protocol was utilized as illustrated in Figure 5.1 and described below.

- All facilitators wore PPE including half-face APR or equivalent and latex gloves whilst in the field.
- The AIG provided transportation to and from the communities for all personnel. The facilitators canvassed each pre-selected community to determine the various types of land uses and buildings within the vicinity. Land uses and buildings that met the assessment criteria and that were determined to be representative of a larger population were targeted. Those sites where asbestos was suspected of being used in the local construction were also targeted.
- At each location, one facilitator would interview the owner or occupant to determine factors such as the age of construction, ownership, and occupants. The site was then divided roughly into quadrants with one surface soil sample collected randomly from each. Quadrants sizes were commensurate with the size of the property. If asbestos debris were visible at the surface it was noted by the facilitator and a sample was collected within an adjacent area from the same quadrant where there was no visible contamination (occasionally samples were collected of obvious asbestos debris, rock fragments or pure fibre to document its existence and to allow laboratory assessment of the fibre type but these accounted for a very small percentage of the overall sample set).

- The stand and improvements were sketched on the field data forms and the locations of visible asbestos contamination noted along with sample locations. The location of the stand was mapped using a hand-held GPS receiver (Garmin).
- At each quadrant sample sites (soil) were sprayed/misted with water to keep down dust during collection. The soil was scraped from the surface at several locations over an area of roughly one square meter. The quantity of soil varied between facilitators and sites, but generally consisted of approximately 10 – 20 grams.
- Building material conditions were assessed (qualitatively) and identified on the Data Form. A sample of suspect building material was collected (typically 4 cubic centimetres) and placed in a vial or plastic sack and sealed. Where material was obviously not asbestos (such as a tin roof), no sample was collected.
- Samples were double checked for correct labelling (labels match the data form) and stored in sealed containers (10 ml plastic vials or zip-lock plastic bags).
- All sampling equipment was double rinsed with water between each sample location to prevent cross-contamination of samples.
- All equipment was cleaned prior to storage after the completion of each day's sampling prior to leaving the site.
- All facilitators double rinsed their boots/shoes and disposed of latex gloves along with wiping down their APRs prior to removal.
- All samples were transported back to lab in Grahamstown for sorting and analysis (or shipping to the independent laboratory).
- Laboratory analysis was completed per the preferred methodology as described in Chapter 4.

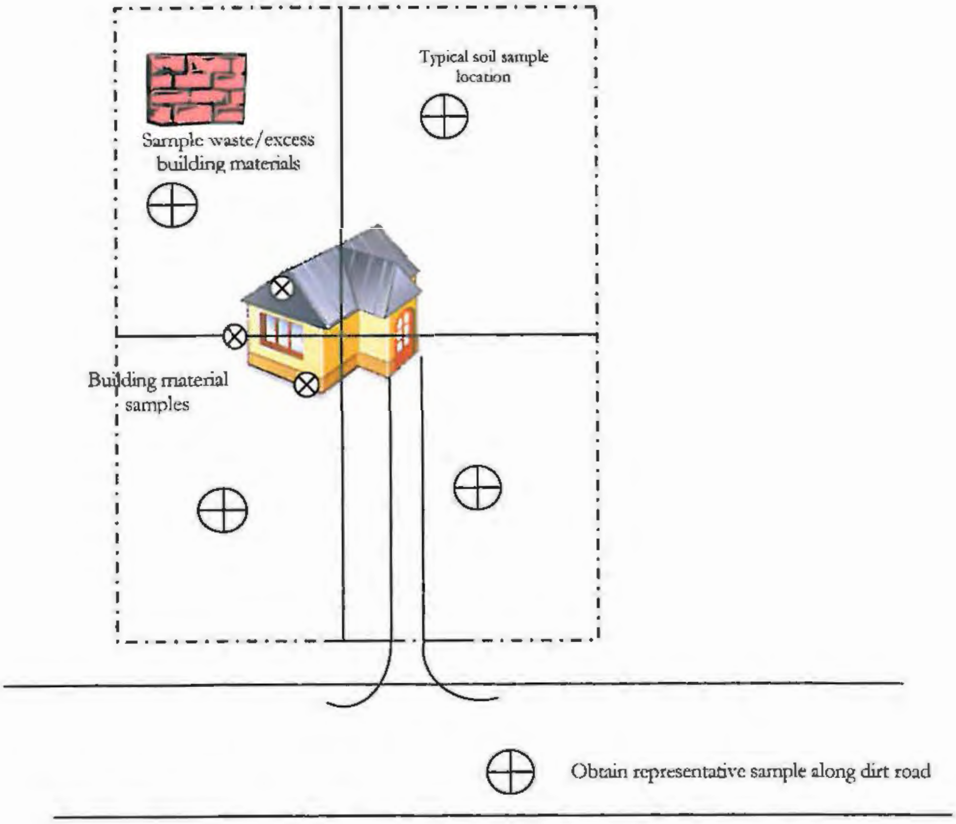


Figure 5.1: Example of typical residential stand with representative sample locations

One of the criteria used in the development of the risk assessment for the Study Area (see Chapter 6) is the condition of the contaminated media, in particular, the building materials accessible by building occupants. Building materials were assessed as part of this screening-level survey in order to ascertain the types of building materials used, the relative percentages of contaminated building materials, their condition and ultimately to inform the risk assessment process as a potential source of environmental exposure. The building material assessment included a determination of the incidence of asbestos contamination (using the preferred laboratory methodology described in Chapter 4) and the condition of the material as a proxy for its ability to release fibres if disturbed.

Soil and building material samples were not collected at all residences. For instance, at certain sites, only soil was obtained for analysis while at others, only building material samples were assessed. These discrepancies are due to different factors including the judgment of the inspector, the wishes of the property owner and physical site constraints. It should also be noted that not all building materials were sampled at each location. Samples were not collected from materials that were obviously or visually determined in the field to not contain suspect asbestos fibres. For instance, wood, corrugated metal and plastic or fibreglass materials were typically not sampled. However at the majority of sites, at least one sample was obtained from each suspect building material of homogeneous appearance and surface soil samples were obtained from more than one (typically three) locations from the site. For all communities combined the average was 2.9 soil samples and 1.4 building material samples per home.

The facilitators were trained by the author to complete a rapid visual assessment of building materials and record the results on the field Data Form. The following definitions were used by the facilitators with respect to building material condition:

Good: Non-friable building materials that are covered with a surface sealant (such as paint) that adequately covers the material keeping it from exposure to the elements and from disturbances from occupants. The material is free of any substantial defects, cracks, peeling surfaces, or other visible problems and is not friable.

Fair: Non-friable building materials that are covered with a sealant but the surface is showing signs of poor maintenance, peeling of the surface layer, partial exposure to the elements or occupants, signs of minor structural problems such as cracks, loose joints, damage, etc. The damaged/poorly maintained sections do not visually appear to represent more than ten percent of the building material's surface area. The damaged portion is friable whereas the remainder is not friable.

Poor: Building material that does not contain an adequate sealant layer, or where one is non-existent. The subsurface is exposed to the elements and occupants and/or the material is significantly deteriorated with cracks, loose joints, damage or other significant problems. The damaged portions represent greater than ten percent of the building material's surface area. The damaged portion is friable or easily releases visible dust when disturbed.

The results of the building materials condition assessment are reported per the methodology adopted for this research. It is important to note that this methodology was adopted because it provides an efficient means of visual assessment that requires very little preparatory training of the facilitators. Appendix A is a sample of the field Data Form completed at each location surveyed during the screening-level assessment.

5.2.1. Methodology for the detailed survey of Ga-Mopedi

As a result of the targeted nature of the selection of sites during the screening-level survey it was not possible to accurately extrapolate the results to non-sampled sites or communities. The inability to statistically evaluate the results limited their usefulness for remediation planning. It was thus determined to complete a detailed door-to-door survey in one community determined to be representative of the Study Area. The community of Ga-Mopedi, approximately 1 650 residents, was selected as it represents a High Risk Community in very close proximity to one or more former mine sites. Additionally, the sampling work completed in the screening-level survey was robust enough to provide an adequate comparative analysis. The medium sized community (436 homes) is somewhat smaller than the mean average for the Study Area (mean = 582, range is 1 - 4 265) but is otherwise representative of a significant number of the 36 communities surveyed. A similar house-to-house survey in Prieska (REDCO 2007) represented the larger, peri-urban communities within the Study Area whilst Ga-Mopedi is more closely associated with the small to medium sized rural village. A total of 19 homes were surveyed in the screening-level assessment, of which, 18 (95%) were found to be contaminated with asbestos tainted soil, building materials or both. Of the 36 communities surveyed, approximately 41 percent contained contamination rates of 95% or higher.

The detailed investigation of Ga-Mopedi included a house to house survey of all accessible stands/home sites (where multiple dwellings were located on each stand) within the community limits as defined by the S.A. Census boundary data (South Africa Census 2001). It also included samples from other land uses including schools, playgrounds and roads. Home sites were digitized from aerial photogrammetry (South Africa Directorate of Surveys and Mapping 1984) into a

GIS database and plotted to aid in the field survey efforts. Each residence was surveyed (assuming the occupant's permission was given) using the protocol described above. A total of 321 homes were surveyed as part of the detailed community survey. The results are presented in Table 5.4. Building materials were not sampled at the same level of intensity as soils due to the need to more accurately quantify the extent of soil contamination throughout the community. A total of 1 335 soil samples and 151 building material samples were collected for analysis. The analysis protocol was similar to that described above with the exception that all samples were analysed by an independent laboratory in the United States (Omni Labs).

5.3. Overall results of residential land use screening-level surveys

The following tables (5.1 through 5.3) are a detailed break-down of the housing stock surveyed per community within the Study Area. Figure 5.2 summarizes the total number of homes surveyed for the Study Area combined and their respective types of contamination present. Figure 5.3 identifies the locations of the 29 communities where residences were sampled as part of the screening-level assessment. Figure 5.7 provides an example of the results of residential land use mapping for one of the 29 communities (Ga-Mopedi) within the Study Area. Within the North West Province, due to the provincial boundary adjustment, only one community (Pomfret) was surveyed. A visual inspection revealed contamination present surrounding the former mine site (after company-sponsored rehabilitation) and adjacent to the residential areas in open space/recreational areas. One home determined to be representative of the entire community (tract housing) was visually surveyed (within the Esperanza Village). The homes within this community contained homogenous building materials. No asbestos building materials (n=5) were identified and a single composite soil sample collected from four separate locations within the stand was NAD.

Eighty-three percent of home sites surveyed revealed some form of contamination (n=259). The most common form of contamination identified with respect to the percent of samples was building materials (79%, n=214) with soil contamination found at 67% of the homes (n=233). Whilst 83% of the homes surveyed contained at least one form of contamination (soil or building materials), only 43% of the homes where both soil and building materials were surveyed were found to contain both types of contaminated media (n=113). The overall likelihood that a given home site, suspected of being contaminated with asbestos (either soil or building materials or both), is actually contaminated with at least one form of asbestos pollution is almost twice the rate of the potential for it to have both forms of contamination present. This finding has implications for the overall determination of community contamination rates and for the potential remediation of asbestos pollution.

5.3.1. Residential land use building material laboratory results

The basic building materials most commonly found to contain asbestos in homes were block, foundation slab materials (concrete and foundation block), bricks, mortar, and plaster. Many of these are made locally (often at the home site) with a clear predilection for locally obtained materials. Roof materials were not commonly selected for sampling as a visual assessment could easily identify asbestos containing cement roofing sheets, from other (non-asbestos) types of roofing materials (the most common of which is cement tiles and corrugated iron). The ACBM roofs encountered by this survey were of the commercially supplied corrugated asbestos cement variety. These typically contain a mix of crocidolite and chrysotile asbestos ranging from 40 to 50 percent of the material's make-up. These roofs do possess the ability to release fibres, in particular when they are disturbed however they are not as easily accessible on a routine basis as the other forms of building materials and were thus typically not sampled as part of this research.

Table 5.1: Results of Residential Surveys per Community for the Study Area based on the Results of Laboratory Analysis (Using the Selected Methodology Described in Chapter 4)

Community	Total Number of Homes Reported in the Community	Total Number of Homes Surveyed/(%)	Number of Soil Samples/Asbestos Detected	Number of Building Material Samples/Asbestos Detected	Number of Homes Testing Positive for Soil Contamination/ Surveyed	Number of Homes Testing Positive for Bldg Material Contamination/ Surveyed	Number of Contaminated Homes/ Surveyed (%) [Soil or Bldg Material]
Bankhara / Bodulong	980	2 (0.2%)	7/0	1/0	0/2	0/0	0/2 (0%)
Draghoander	1	1 (100%)	1/0	0	0/1	0/0	0 /1 (0%)
Kathu	6	2 (33%)	2/2	0	2/2	0/0	2/2 (100%)
Koegas	1	1 (100%)	1/1	0	1/1	0	1/1 (100%)
Kuruman	1636	2 (0.1%)	7/1	0	1/2	0	1/2 (50%)
Owendale	12	1 (8.3%)	NS	1/1	0/1	1/1	1/1 (100%)
Prieska	3235	6 (0.2%)	NS	7/5	NS	3/6	3/6 (50%)
Westerberg	2	1 (50%)	NS	1/1	NS	1/1	1/1 (100%)
Wrenchville	4265	7 (0.2%)	24/5	8/5	2/7	5/6	5/7 (71%)
Batlharos	3031	41 (1.4%)	113/52	66/48	29/41	32/41	35/41 (85%)
Galotolo	94	5 (5.3%)	20/12	15/11	4/5	5/5	5/5 (100%)
Ga-Mopedi	333	19 (5.7%)	77/56 (1untested)	27/18 (1 undetermined)	16/17	10/11	18/19 (95%)
Ga-Motsamai	119	9 (7.6%)	21/7	19/13	3/5	9/9	9/9 (100%)
Heuningvlei	871	46 (5.3%)	110/46 (4 missing)	62/43 (1 missing)	22/45	26/31	33/46 (72%)

Community	Total Number of Homes Reported in the Community	Total Number of Homes Surveyed/(%)	Number of Soil Samples/Asbestos Detected	Number of Building Material Samples/Asbestos Detected	Number of Homes Testing Positive for Soil Contamination/ Surveyed	Number of Homes Testing Positive for Bldg Material Contamination/ Surveyed	Number of Contaminated Homes/ Surveyed (%) [Soil or Bldg Material]
Gasehubane	91	5 (5.5%)	20/3	4/4	4/4	2/5	4/5 (80%)
Maruping	1703	17 (1%)	39/8	25/8	12/17	6/15	12/17 (71%)
Masonkong	73	11 (15%)	34/16	15/12	8/8	9/10	10/11 (91%)
Pietboos	57	2 (3.25%)	4/2	5/2	1/1	2/2	2/2 (100%)
Gateshikedi	60	4 (6.7%)	16/3	2/2	1/4	2/2	3/4 (75%)
Sedibeng	319	17 (5.3%)	50/27	19/16	14/14	12/14	16/17 (94%)
Seven Miles	423	6 (1.4%)	7/4	9/2	4/6	1/5	4/6 (67%)
Sloja	770	2 (0.3%)	8/5	5/5	2/2	1/1	2/2 (100%)
Tshukudung	115	3 (2.65%)	16/0	3/3	0/3	2/3	2/3 (67%)
Tsineng	601	5 (0.8%)	12/1	5/5	1/3	4/4	4/5 (80%)
Seodin	456	3 (0.7%)	9/2	2/1	1/3	1/2	1/3 (33%)
Maipeng	325	12 (3.7%)	41/19	15/12 (1 untested)	7/10	10/12	12/12 (100%)
Magojaneng	1080	17 (1.6%)	70/30	21/18	13/17	14/17	17/17 (100%)
Magobing	109	9 (8.3%)	36/19	11/11	7/9	8/8	9/9 (100%)
Vergenoeg	165	3 (1.8%)	7/0	6/4	0/3	2/3	2/3 (67%)
Totals: 29	**20933**	**259 (1.2%)**	**752/321**	**354/250**	**155/233**	**168/214**	**214/259 (83%)**

NS = Not Sampled

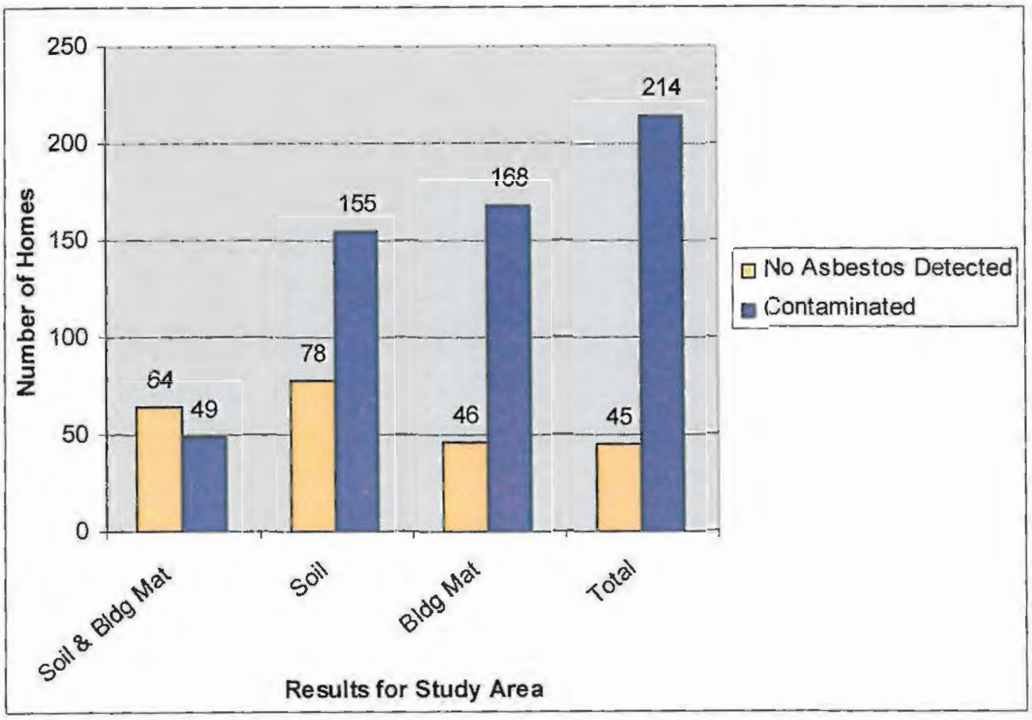


Figure 5.2: Number of contaminated homes surveyed and type of contamination per category. The total is a combined result for all residential sites surveyed (n=259).

A total of eleven different building material classifications were recorded by the surveys. These were aggregated and the results for the major categories are provided in Tables 5.2 and 5.3. Due to subjectivity in the surveys, there are likely minor discrepancies in the building material descriptions. For example, mortar, concrete and plaster may in fact be made from the same material as well as blocks and bricks. In addition, many foundation slabs are made of poured concrete again increasing the chance for confusion. This is due to the variety of descriptions used by different facilitators. Some aggregation of descriptions was completed at the author's discretion but all reported sample results were discrete with no double counting. Table 5.2 is a summary of the building material results for residences within the Study Area.

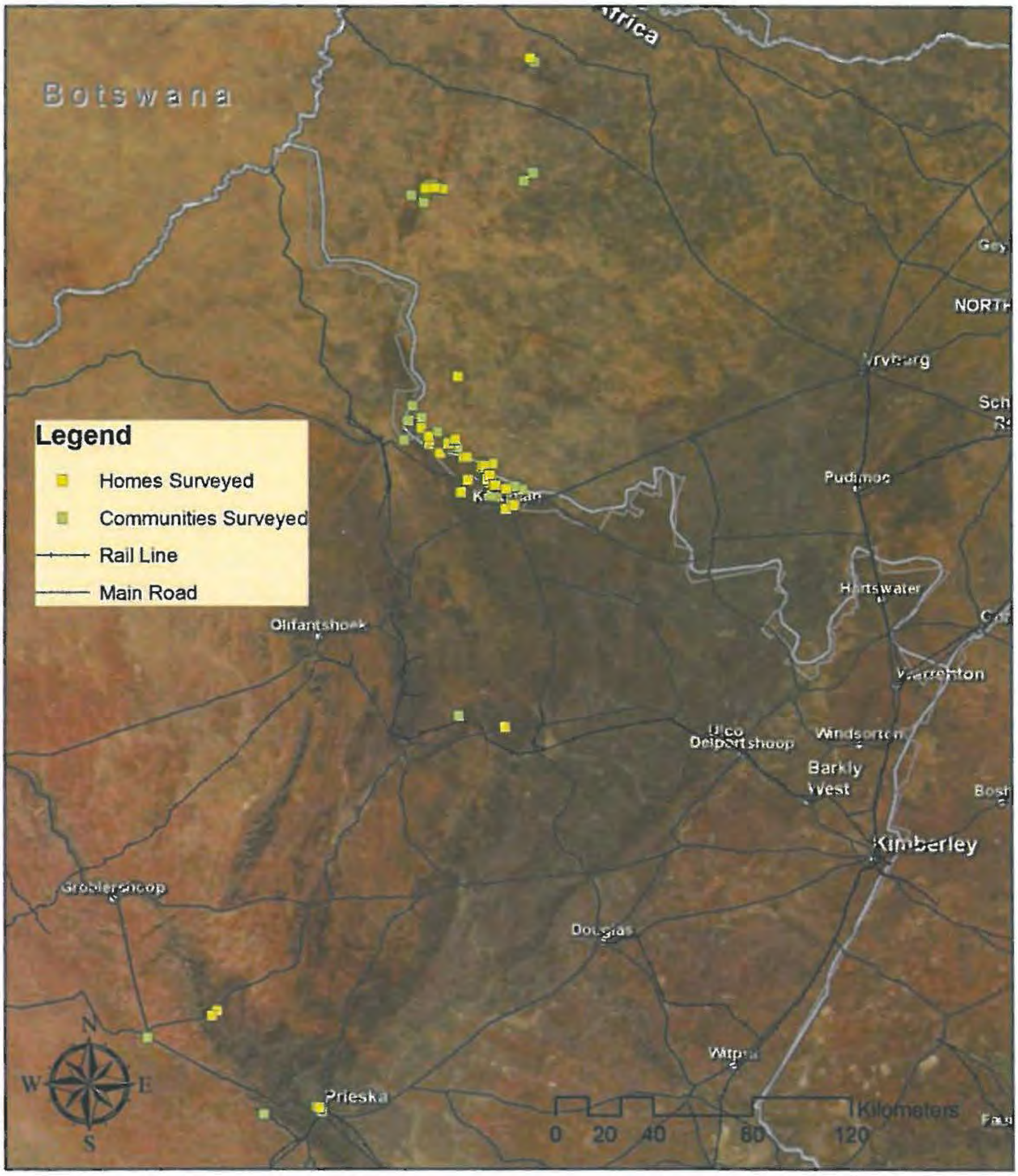


Figure 5.3: Locations of 29 communities where homes were surveyed in Study Area

Table 5.2: Results of residential surveys of building materials within the Study Area

BUILDING MATERIAL	NUMBER OF SAMPLES	POSITIVE FOR ASBESTOS
Block	111	99 (89%)
Floor/Foundation Slab Materials	109	60 (55%)
Brick	56	38 (68%)
Plaster	25	10 (40%)
Mortar	20	17 (85%)
Totals	321	224 (70%)

Table 5.2 indicates that 224 (70% [n=321]) of the samples analysed contained some level of asbestos contamination with block having the highest rates of contamination, followed by mortar, then bricks. Observations during the collection of samples indicated that blocks are often made locally (many times at the home site) and that locally available soil materials, including asbestos contaminated soil and is some cases, pure asbestos fibres, are mixed into the cement material. The asbestos fibres provide additional bonding strength to the mix. Photos 5.1 and 5.2 are a typical home site (Heuningvlei) showing the remaining pile of soil used for block making and extra blocks stockpiled nearby.

Photo 5.1: Image of crocidolite contaminated soil used for local block making in Heuningvle (Photo by author)

Photo 5.2: Image of locally made blocks used for walls at home in Heuningvlei (Photo by author)


Photo 5.3: Floor slab and block at the Gasehubane Primary School. Note the deteriorating concrete slab and block. The soil in the foreground is contaminated with crocidolite fibres. (Photo by author)

5.3.2. Residential land use building material condition assessment

Table 5.3 presents the results of the condition assessment of selected building materials for residences based on the screening-level community surveys. These results indicate that 62 of the 65 samples (95 percent) that were assessed for their condition were also contaminated with asbestos fibres. Of these, 100 percent of the plaster samples were found to be poor condition, 69 percent of the floor/slab foundation materials and 68 percent of the block building materials were also found to be in poor condition resulting in an overall rate of 61% of the contaminated materials sampled. These results (as evidenced by photos 5.1 through 5.3) indicate the overall substandard condition of the building material within the Study Area. These conditions are conducive to exposures to the occupants from routine daily activities and environmental factors of wind and rain.

Table 5.3: Results of Residential Building Materials Condition Assessment

BUILDING MATERIAL	NUMBER OF SAMPLES	POSITIVE FOR ASBESTOS	RESULTS OF CONDITION ASSESSMENT	ASBESTOS CONTAMINATED AND CONDITION
Block	31	31	Good = 2 Fair = 8 Poor = 21	Good = 2 (6%) Fair = 8 (26%) Poor = 21 (68%)
Floor/ Foundation Slab Materials	15	13	Good = 2 Fair = 3 Poor = 10	Good = 2 (15%) Fair = 2 (15%) Poor = 9 (69%)
Brick	11	11	Good = 5 Fair = 3 Poor = 3	Good = 5 (46%) Fair = 3 (27%) Poor = 3 (27%)
Mortar	4	4	Good = 1 Fair = 1 Poor = 2	Good = 1 (25%) Fair = 1 (25%) Poor = 2 (50%)
Plaster	4	3	Good = 0 Fair = 0 Poor = 4	Good = 0 Fair = 0 Poor = 3 (100%)

5.4. Screening-level community survey overall results for schools

Schools are the second most often assessed land-use after residential in the Study Area. A total of 45 individual schools were assessed as part of the community survey including day-cares and pre-schools with a total of 303 soil and building material samples. The screening- level assessment completed for these 45 schools do not represent a comprehensive study of the schools within the affected regions, nor does it represent a comprehensive survey of any individual site. It rather serves to highlight the incidence of asbestos contamination (from either soils and/or building materials) at schools within the distances identified by the preliminary risk mapping and/or the judgment of the community facilitators. The following table (5.4) identifies by community the number of public schools assessed within the Study Area (primary, secondary and high schools) as compared to the total number of existing schools as identified by the South Africa government (South African Census 2001). These results exclude pre-schools which are reported separately.

These finding represent the majority of public schools within the Study Area (80 percent) and are thus illustrative of the conditions likely to be encountered in the remaining non-surveyed schools. Of particular concern is the overall high number of school sites 67 percent) with either asbestos contaminated soil and/or building materials. Of these, 50 percent contained soil contamination. A total of 55 building material samples were assessed for their condition with 84 percent rated as poor. This is important as the soil samples were typically obtained from locations within the schoolyard footprint where learners walk and recreate. Additionally, the soils in these areas are typically devoid of vegetation and the fibres could easily be entrained due to disturbances (see results of activity-based sampling discussion in Chapter 6).

Primary and middle schools were more likely to be contaminated than high schools. This is another disconcerting fact given that age of first exposure is a determinant in the risk of asbestos related disease (Berman and Crump 1999; ATSDR 2003). The schools (including pre-schools surveyed as part of this research) listed in Table 5.6 were identified by this research as having soil contamination present within the school grounds and in areas regularly traversed by children and/or contaminated building materials.

Table 5.4: Results of Public School Surveys per Community for the Study Area (excludes pre-schools) based on the Results of Laboratory Analysis (Using the Selected Methodology Described in Chapter 4)

Community	Total Number of Schools Reported in the Community	Total Number of Schools Surveyed/(%)	Number of Soil Samples/Asbestos Detected	Number of Building Material Samples/Asbestos Detected	Number of School Testing Positive for Soil Contamination/ Surveyed	Number of School Testing Positive for Bldg Material Contamination/ Surveyed	Number of Contaminated Schools/ Surveyed (%) [Soil or Bldg Material]
Bankhara / Bodulong*	1	1 (100%)	9/0	2/1	0/1	1/1	1/1 (100%)
Kuruman	1	1 (100%)	5/1	1/0	1/1	0/1	1/1 (100%)
Prieska	7	6 (86%)	22/4	10/3*	4/6	2/4	4/6 (67%)
Wrenchville	3	2 (67%)	21/0	1/0	0/2	0/1	0/2 (0%)
Jenhaven	1	1 (100%)	1/0	3/0	0/1	0/1	0/1 (0%)
Batlharos	3	3 (100%)	16/3	3/1	2/3	1/1	2/3 (67%)
Ga-Mopedi	3	2 (67%)	11/8	7/4	2/2	1/2	2/2 (100%)
Ga-Motsamai	1	1 (100%)	4/0	1/1	0/1	1/1	1/1 (100%)
Heuningvlei**	3	3 (100%)	13/11	13/11	3/3	2/2	3/3 (100%)
Gasehubane	2	1 (50%)	4/2	2/2	1/1	1/1	1/1 (100%)
Maruping	3	3 (100%)	15/1	6/1	1/3	1/3	2/3 (67%)
Ncweng	2	2 (100%)	Excluded†	Excluded†	Excluded†	Excluded†	1/2 (50%)
Sedibeng	1	1 (100%)	5/4	2/2	1/1	1/1	1/1 (100%)
Tshukudung	1	1 (100%)	4/0	2/0	0/1	0/1	0/1 (0%)

Community	Total Number of Schools Reported in the Community	Total Number of Schools Surveyed/(%)	Number of Soil Samples/Asbestos Detected	Number of Building Material Samples/Asbestos Detected	Number of School Testing Positive for Soil Contamination/ Surveyed	Number of School Testing Positive for Bldg Material Contamination/ Surveyed	Number of Contaminated Schools/ Surveyed (%) [Soil or Bldg Material]
Seodin	2	1 (50%)	2/0	2/1	0/1	1/1	1/1 (100%)
Maipeng	1	1 (100%)	4/1	2/2	1/1	1/1	1/1 (100%)
Magobing	1	1 (100%)	4/0	1/1	0/1	1/1	1/1 (100%)
Mothibistad	8	4 (50%)	22/1	6/1	1/4	1/3	1/4 (25%)
Vergenoe g	1	1 (100%)	4/0	1/1	0/1	1/1	1/1 (100%)
Totals: 20	**45**	**36 (80%)**	**166/36**	**65/32**	**17/34**	**16/27**	**24/36 (67%)**

* Communities have combined school

** One school identified in the database is not located within the Heuningvlei Community and was thus omitted.

† The former Ncweng Primary School was closed due to extensive contamination from asbestos. Extensive soil sampling was completed but omitted from these results in order to not skew the results. The new school location was surveyed and found to be free of soil contamination. The former school is still standing (but unused) and is therefore included in these results.

Note: Due to the boundary revision between the Northern Cape and the North West Provinces, no schools were surveyed in North West.

Photo 5.4: Children playing in contaminated schoolyard

Old Ncweng Primary School (recently rehabilitated former asbestos dump is in the background). Soils in the area where the children are playing are contaminated with crocidolite asbestos at 1-3 percent. (Photo by author)

Table 5.5: Surveyed schools within the Study Area with contaminated soil and/or building materials (by Community and including pre-schools)

COMMUNITY	SCHOOL	RESULTS OF SOIL ANALYSIS	RESULTS OF BUILDING MATERIAL ANALYSIS
Bankara	Bankara-Bodulong Combined School	NAD	5-10% chrysotile
Bodulong	Recweletse Pre-School	Trace	Not Tested
Heuningvlei	Tsoe Primary School	1-3% crocidolite fibres	Block, Foundation, Mortar, Slab: 3-5%+ crocidolite
	MP School	Trace levels of crocidolite fibres	Not Tested
	OP School	Trace levels of crocidolite fibres	Foundation is 10-30% crocidolite
Prieska	JJ Drywer School	Trace levels of crocidolite fibres	Plaster and Roof – crocidolite & chrysotile
	Van Niekerk Street High School	Trace levels of crocidolite fibres	Not Tested
	Heuwelsig High School	Trace levels of crocidolite fibres	Roof – chrysotile
	Initia Primary School	Tracel levels of crocidolite	NAD
Kuruman	Primary School	Trace levels of crocidolite fibres	NAD
	Willie Wallie Pre-School	Trace levels of crocidolite fibres	NAD
Batlharos	Makuolokwe Middle School	3-5% crocidolite	Not Tested
	Lesedi High School	Trace levels of crocidolite fibres	NAD
Maruping	Gamohana Middle School	Trace levels of crocidolite fibres	NAD
	Primary School	NAD	Foundation: Trace levels of crocidolite
Sedibeng	Primary School	Trace levels of crocidolite fibres	5-30% crocidolite in foundation and block
Gasehubane	Primary School	Trace levels of crocidolite fibres	3-5% crocidolite in block and floor
Maipeng	Primary School	5-10% crocidolite fibres	5-10% block
Mothibistad	Segonyama Primary School	Trace levels of crocidolite fibres	Roof: crocidolite & chrysotile mix
Ga-Mopedi	Khiba Middle School	3-5% crocidolite fibres	Foundation & block up to 20% crocidolite
	Primary School	1-3% crocidolite fibres	NAD
Ga-Motsamai	Ineeling Primary School	NAD	Floor slab: 1-5% crocidolite
Gasehubane	Primary School	Trace levels of crocidolite	Block: 3-5% crocidolite

Community	**School**	**Results of soil analysis**	**Results of building Material analysis**
Magobing	Primary School	NAD	Block: 5-10% crocidolite
Maipeng	Primary School	5-10% levels of crocidolite	Block: 5-10% crocidolite
Sedibeng	Primary School	1-3% crocidolite in the soil	Foundation & block: up to 30% crocidolite
Seodin	Kudumane Primary	NAD	Plaster: 10-15% crocidolite
Vergenoeg	Primary	NAD	Mortar: 10-30% crocidolite
Totals:	**28 Schools**		

Figure 5.4 is a map of the surveyed locations of schools with soil and/or building materials contaminated with asbestos within the Study Area.

5.5. Screening-level community survey overall results of roads

Dirt covered roads were surveyed within communities in order to determine the presence of asbestos contamination. Based on the total number of samples collected, dirt roads represent the third largest segment of the survey. A total of 29 individual sites were sampled within 15 communities. A total of 61 samples were collected with an overall rate of contamination at 51 percent. Heuningvlei had the greatest number of locations surveyed (nine) with a contamination rate of 56 percent. Table 5.6 identifies by community the number of samples, sites and rates of contamination.

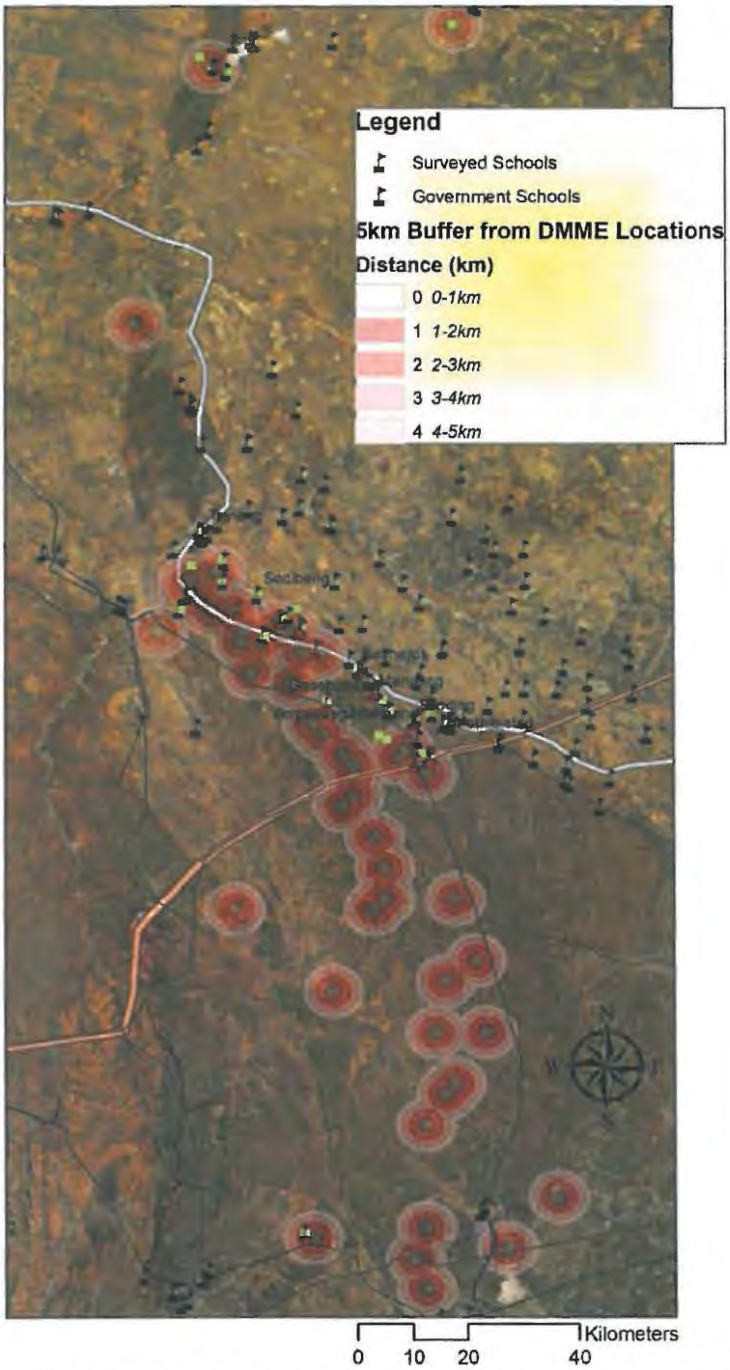


Figure 5.4: Map of Schools Surveyed within the Study Area

A comparison of these results to a previously completed Kgalagadi District Council report indicates consistency (Viridus Technologies 2002). However soil sampling protocols and analysis methods are considerably different between the two investigations with the Kgalagadi report having a higher sampling density per road kilometre surveyed but more constrained to one geographic area. The differences in soil analysis methodologies do not allow for any direct comparisons. The most important findings of the Kgalagadi District report are the significant extent of road contamination and the relatively high levels of airborne exposure (arithmetic mean of 0.52 f/ml [n = 139]) associated with vehicle traffic over gravel or unpaved roads. These airborne exposures from vehicle traffic are discussed in greater detail in the exposure assessment (Chapter 6). Given similar conditions exist in the remaining former asbestos mining regions it is reasonable to assume that similar findings can be expected with respect to exposures and extent of contamination.

Table 5.6: Road samples and results per community within the Study Area

COMMUNITY	ASBESTOS DETECTED/NUMBER OF SAMPLES	ASBESTOS DETECTED/NUMBER OF LOCATIONS
Wandrag	2/2	1/1
Vergenoeg	2/4	1/1
Tshukudung	0/2	0/1
Sloja	1/2	½
Seodin	2/2	1/1
Masonkong	0/1	0/1
Magobing	2/3	1/1
Heuningvlei	8/19	5/9
Gatshikedi	0/2	0/2
Ga-Mopedi	3/3	3/3
Prieska	1/2	1/1
Kuruman*	7/14	3/3
Kougas*	3/3	1/1
Jenhaven	0/1	0/1
Groenwater	0/1	0/1
Totals: 15	31/61 (51%)	18/29 (62%)

* One road surveyed in Kuruman and Kougas were tar surfaced. Samples were collected along the dirt edges.

Figure 5.5 is a map prepared from the GIS database created as part of this research. The roads in red were sampled as part of the community survey efforts. The green dots represent the sample locations and the red road segments represent the corresponding length of road assumed to be contaminated based on the screening level assessment. The contaminated road segments represent +/- 19.7 kilometres of unpaved road surface. The remaining road segments (in brown) represent approximately 102 km of roads, of which, only 7.2 are paved. The road samples were typically obtained near road intersections and within the proximity (typically less than one kilometre) of a community. The results do not represent a systematic survey of the road system. Given the results of the Kgalagadi District study (100% contaminated), and the overall percent of contaminated roads identified by this research (68%) within the Northern Cape Province (including portions of the former North West Province), it advisable to presume that a significant portion of the roads not sampled (those road segments in brown on Figure 5.5) may also contain contaminated segments. It is also important to note that the road segments identified in the GIS database are based on data provided by the South Africa Municipal Demarcation Board (2000). Individual unpaved and unnamed streets within communities are frequently not mapped by this dataset. For example the roads sampled within the Ga-Mopedi community (three locations) are not mapped but still represent road segments where exposures may occur and that will require remediation of the contaminated surfaces. Therefore, additional analysis will be required using other overlay data (such as aerial photogrammetry) and more detailed and systematic sampling to more accurately determine the linear remediation requirements.

Figure 5.5: Example of a plot of the roads surveyed in the communities of Sedibeng and Masonkong

Figure 5.5: Example of a plot of the roads surveyed in the communities of Sedibeng and Masonkong with brown segments representing non-surveyed locations and the red segments representing those segments found to contain asbestos contamination in at least one location.

All roads not sampled by this survey or previous surveys should be sampled to determine the presence of asbestos. The segments identified as containing asbestos contamination should be surveyed at increasing levels of resolution in order to isolate those sections where contamination exists. Another concern is those road segments not identified as designated roadways but which nonetheless are utilised by local traffic (and pedestrians) within the communities. These segments are also typically located in very close proximity to dwellings and are most often dirt covered, thus there disturbance by vehicle traffic creates the opportunity for copious amounts of asbestos laden dust where the road surfaces are contaminated with fibres. Ten of the fifteen communities represented by road samples were found to be contaminated. Asbestos concentrations in the soil ranged from trace levels to 20-30 percent crocidolite fibres.

5.6. Screening-level community survey overall results for other land uses

Other land uses were surveyed in the Study Area but to a lesser extent than homes, schools and roads. Table 5.8 identifies the total number of other land uses and their respective rates of contamination below based on the findings of this research. The other land uses surveyed are primarily public buildings (such as administrative/tribal offices), police stations, post offices, churches, and open space.

Table 5.7: Other surveyed land uses within the Study Area with the number of sites surveyed within each land use and their respective rates of contamination (either building materials, soil or both)

LAND USE	NUMBER OF SITES SURVEYED	NUMBER & PERCENT CONTAMINATED
Public Buildings	17	7 (41%)
Hospitals/Clinics	7	4 (57%)
Police Stations / Post Offices	5	2 (40%)
Churches	11	8 (73%)
Private Businesses	16	10 (63%)
Open Space, Parks & Cemeteries	33	21 (64%)
Totals	**89**	**52 (58%)**

Total rates of contamination for all land uses were generally consistent with the other land uses previously discussed (homes, schools and roads). Taken together there is a high potential for exposures to the workers, occupants and general public based on the presence of asbestos containing materials. For instance, the US EPA (1988) estimated that 20 percent of public and commercial buildings in the United States contained friable asbestos building materials with approximately five percent of these containing sprayed on types of asbestos surfacing material. No estimates for South Africa were found. This compares to an average of 60.3% of the public areas surveyed as part of this research. It is noted as well that of all of the land uses surveyed, the least "targeted" is that of those that are public in nature. This is due to a lower level of knowledge as to the building conditions of many of these land uses as compared to the other uses (in particular homes). The selection of sites for survey was therefore more random in nature and thus the results may be more easily extrapolated to other similar conditions within the Study Area.

5.7. Detailed survey results for Ga-Mopedi

A comparison of the results with the screening level assessment indicates that overall, approximately 26.2 percent (n=321) of the homes are contaminated with either asbestos contaminated soil, building materials or both. The results of the soil analysis indicates that 80 of the 321 homes surveyed were contaminated with soil ranging from trace levels of contamination (less than one percent per the preferred laboratory methodology) to approximately ten percent. As previously noted, using the preferred methodology for analysis, the positive identification of asbestos, at any level, is sufficient to generate airborne exposures. The results of the building material assessment indicated that only 6% of the building materials (n=151) are also contaminated with asbestos.

The results for the number of homes contaminated in Ga-Mopedi (26.2 percent) are in contrast to the average contamination rate of 36 percent for all homes in the twelve Ga-Mafefe communities according to Felix (1997). The differences between the surveys completed as part of this research and the results of Felix may be explained by the differing methodologies between the two studies. Felix (1997) surveyed all households (1 766) within the Ga-Mafefe communities using structured interviews which relied upon the occupant's knowledge of the building construction and site history. These results may have included occupants who were unaware of the presence of asbestos that exists in small quantities. In particular, soils with trace levels of contamination are very difficult to detect with the naked eye. A very large and detailed study of the individual communities within Ga-Mafefe would be required in order to directly compare the results of the two studies.

A report was commissioned by the Northern Cape Provincial Government's Department of Tourism, Environment and Conservation (DTEC) and completed by REDCO consultants. The report, entitled, "An Audit of the Asbestos Contaminated Buildings in the Northern Cape Province – Prieska Report" is not dated but was reportedly completed in 2007. Prieska contains approximately 3 235 stands within four blocks. The REDCO survey completed a house to house survey of each of the stands and collected a total of 9009 samples of soil or building materials. The REDCO findings indicated that 969 homes (30 percent) were found to contain either asbestos contaminated soil, building materials or both. It is also important to note that the laboratory methodology used by REDCO did not make use of any microscopic analysis, relying instead upon sieving and visual observation for fibres. These were primarily concentrated in one area (Rooiblok) with considerably less contamination within the other sections of the community (see Figure 5.6).

Figure 5.6: Map of the Rooiblok section of Prieska (red colours representing the stands prioritized for clean-up from the REDCO study - 2007).

Table 5.4 is a summary of the initial screening level survey of Ga-Mopedi completed in 2006, the more detailed follow-up survey completed in 2009 and the two other surveys completed in South Africa (Prieska 2007 and Ga-Mafefe – 1997). The other two surveys are presented for purposes of comparison to determine the congruence of the various efforts. Section 5.10 provides a discussion of the implications of these results. Figure 5.7 is a map of the homes surveyed in 2006 screening level assessment and of the house to house survey home sites completed within the Ga-Mopedi community and Figure 5.8 is a map of the results of the detailed Ga-Mopedi survey.

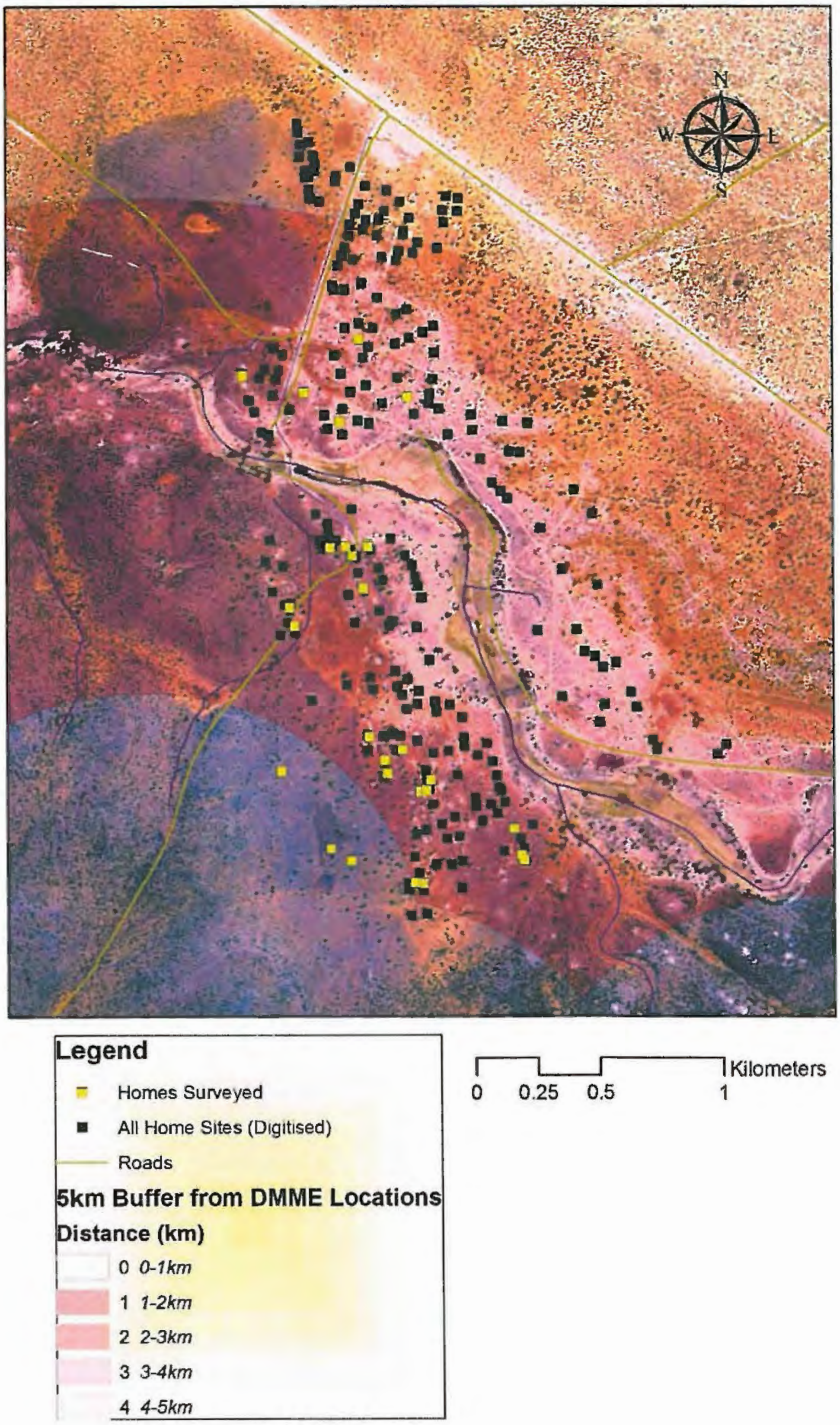


Figure 5.7: Locations of homes surveyed in screening-level risk assessment versus all homes identified in the detailed door-to-door survey

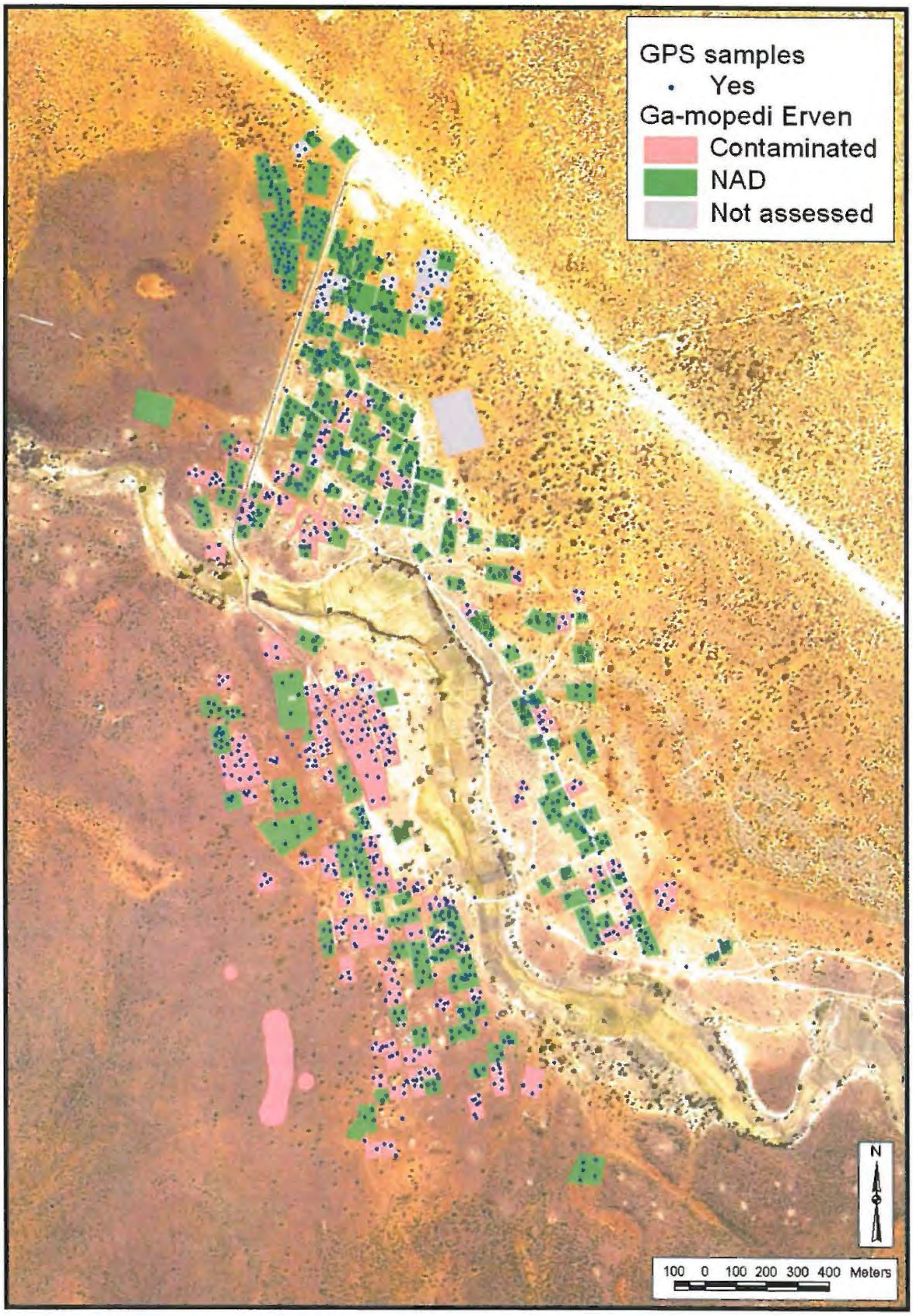


Figure 5.8: Map of the detailed survey results for Ga-Mopedi

Table 5.8: Results of Detailed Residential Survey of Ga-Mopedi and Comparisons

Community	Total Number of Homes Reported in the Community	Total Number of Homes Surveyed/(%)	Number of Soil Samples/Asbestos Detected	Number of Building Material Samples/Asbestos Detected	Number of Homes Testing Positive for Soil Contamination/ Surveyed	Number of Homes Testing Positive for Bldg Material Contamination/ Surveyed	Number of Contaminated Homes/ Surveyed (%) [Soil or Bldg Material]
Ga-Mopedi (Screening-Level Survey)	333	19 (5.7%)	77/56 (1untested)	27/18 (1 undetermined)	16/17	10/11	18/19 (95%)
Ga-Mopedi (Detailed Survey)	436	321 (74%)	21/7	151/9	80/321	9/151	84/321 (26%)
Prieska Survey (by REDCO 2007)	3235	3235 (100%)	Not Reported	Not Reported	Not Reported	Not Reported	969/3235 (30%)
Mafefe Survey (by Felix 1997)	1766	1766 (100%)	Not Reported	Not Reported	Not Reported	Not Reported	636/1766 (36%)
Totals:	**20933**	**259 (1.2%)**	**752/321**	**354/250**	**155/233**	**168/214**	**1707/5341 (32%)**

5.8. Analysis of distance to source relationship

The methodology used to select communities for survey and for individual sample sites is described in Chapter 3. However, one of the questions this research sought to shed light on is the relationship between the original source of contamination such as a mine site, dump site or mill and the location of asbestos within the surrounding communities. Felix (1997) had shown no statistical correlation between the extent of residential contamination in those homes closest to the former tailings dumps and those farthest away (a distance of up to approximately 5km for at least two villages). However, the vast majority of the communities in this survey were well within 2-3km of the original mine sites, mills or tailings dumps. Communities surveyed in this research ranged from a distance of less than a few hundred meters (Galotolo for example) from the nearest potential source site to approximately thirteen kilometres (Wrenchville). In fact, due to the information provided by the local facilitators, a number of communities well outside the initial five kilometre radius were surveyed and found to contain asbestos contamination. Communities such as Bankhara, Bodulong, Kuruman, Wrenchville, Kathu, Seven Miles, and Maruping were all outside of the initial preliminary risk analysis of five kilometres. However, many of these communities such as Kuruman and Wrenchville still showed contamination levels at 50 percent and 70 percent respectively. As might be expected, communities in close proximity to the former tailings dumps have residential contamination considerably higher than those more distant.

Figure 5.9 is a graph of the distance from the source point (approximate centre point identified on the RPI database) and an average of the edge of the community (as mapped by the Municipal Demarcation Board) and the nearest sample point. Communities and/or sample points closer than 1km from the presumed source point were listed as 0.5km. This is to account for the fact that the presumed source point typically represents an area (not a specific point) and the areas tend to have multiple source potentials (dump sites, mine adits, etc) located over a large area. Therefore a distance of 0.5km was arbitrarily assigned to account for this variability for those sites within one kilometre of a presumed source point as mapped on the RPI database.

The purpose of this graph is to demonstrate the relationship between the distance from the presumed source point and the level of contamination (as depicted by the percent of homes identified as contaminated) identified by this survey. A total of 36 communities were assessed with an average rate of contamination of 74 percent (SD = 11.51 at CI of 95%) and an average distance of 3.8 km (SD = 1.18 at a CI of 95%) from the source point (minimum of 0.5 km and a maximum of 12.7 km). Rates of contamination ranged from 0 to 100 percent.

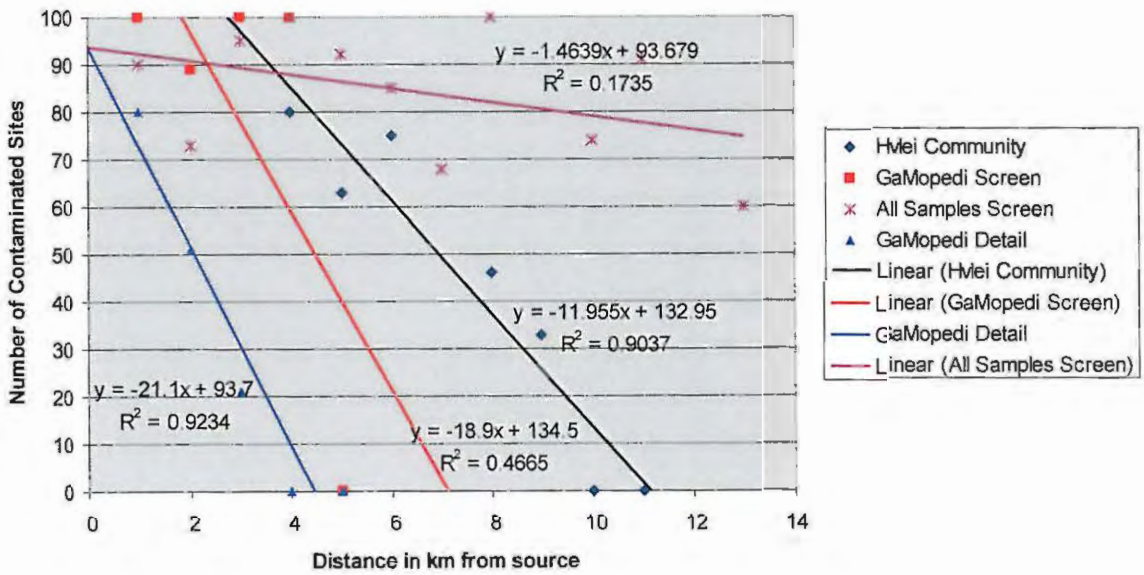


Figure 5.9: Distance from presumed source point versus percentage of contaminated home sites within 36 communities surveyed as part of this research.

Seventeen (45%) of the communities had a 100% rate of contamination for the homes surveyed, and of these, 16 (94%) were within the five kilometre radius. A total of 58% (n=22) of the communities were closer than the average of 3.8km and these had an average contamination rate of 76.4% with an average distance of 1.7km from the source point. This compares to an average contamination rate of 61% at an average distance of 7.6km for the sample set farther than the average of 3.8km. This equals a 2.6% reduction per kilometre. This rate of reduction for the screening-level surveys cannot be extrapolated with any degree of accuracy to other communities in that the numbers used are not averages for entire community but rather reflected the results of targeted surveys. However they do indicate that while contamination rates are the highest within the five kilometre buffer, they do extend well beyond this distance albeit with an inverse relationship. Even at a distance of 12.5+/- km, the rates of contamination range from 33 to 77%.

The rate of reduction calculated for the Ga-Mopedi community can be used for extrapolation as the results are based on a detailed assessment of 74% of the homes. The calculated slope (R^2 value = 0.9234) indicates an almost 20 percent reduction per km distance from the presumed source (ten times greater than that calculated for all communities). However, the calculated rate of reduction is similar to that for the community with the second highest rate of residential sites sampled (Heuningvlei) at R^2=0.09037 with an average rate of reduction of 9.4 percent per kilometre.

5.9. Analysis of contamination rates with age of construction

Another useful test of the data collected by the community surveys was to determine if there as an age dependent variable for the identification of asbestos contaminated sites. Bans of the use of asbestos containing materials in some countries have resulted in a reduction in the use of asbestos in new construction. South Africa has only introduced a ban in 2006 and therefore there have been no legal restrictions on the use of asbestos containing building materials. However, public knowledge as to the health risks of asbestos has reduced its use in many other countries. It is therefore important to determine if the use of asbestos in construction has declined over time or if there is a cutoff date whereby asbestos was no longer used in the construction of buildings within the Study Area.

Building occupants were asked the age of the structure during the site specific surveys and the results recorded in the project database. In many cases, the occupant was not aware of the age of the structure. A total of 113 entries were recorded within eleven communities. These were assessed to determine if there was a correlation between the existence of contamination and age of construction. The range of construction dates for all sites was from 1829 (Moffatt Mission) to 2004. Given the historic nature of the Mission, and its outlier effect on the data set, it was omitted from the analysis. The next oldest site was a school with a construction date of 1898 providing a range of 106 years (n=112). Assessing only the contaminated sites (n = 78) within the data set yielded the same range of construction dates (1898 to 2004) as the oldest and most current construction were both found to be contaminated. The median age of construction for all sites is 1978 and for the contaminated sites is 1970. The standard deviation for all sites was 16.18 years and for only the contaminated sites was 15.52 years (at 95% CI).

Based on these results, there is no statistically significant correlation between the occurrence of asbestos contamination and date of construction. Comparing the likelihood that a given site is contaminated based on the mode date of construction (1978) yields a ratio of 1.17:1 for all sites and 1.05:1 for contaminated sites. There is then an 8% chance that a site was built during or after 1978 but only a 3% chance that the site is contaminated showing a slight declining trend in the use of asbestos building materials or contaminated sites being used for construction. This trend may also be influenced by the fact that the raw asbestos product used for building materials stopped being produced in this region in the 1980's and residual supplies that were once easily accessible have since declined.

This finding points to the ubiquitous nature of the asbestos waste as a source of building material, right up through 2004. In fact, within these communities there are numerous examples of piles of asbestos blocks waiting to be utilized in local construction. There is a high degree of scavenging of building product from abandoned sites and where the soil is contaminated with asbestos fibres and then used in the making of blocks, mortar or cement, it continues to be part of the cycle of contamination. This practice has been documented by Felix (1997), Braun et al. (2001) and was evidenced at numerous locations through this research. There can be no clear distinction between age of construction and whether or not a particular site is contaminated with asbestos as may be the case in countries where asbestos has been banned for use in construction (such as the United States or European Union). Until the residual sources of contaminated soil and building materials are properly removed and disposed of, and the local population properly educated, the continued use of asbestos building materials is likely to occur.

5.10. Discussion

The results of the community surveys have provided a wealth of data from which to assess the extent and severity of contamination within the Study Area. Additionally, the additional qualitative data have been utilised in the risk assessment (see Chapters 6 and 7) to estimate the probable exposures and resulting levels of asbestos related disease in the communities. Maps of contamination for all communities where geographic coordinates were collected at sample points have been generated. Due to equipment failures the sample coordinate data were not collected at nine communities during the field investigations. Detailed addresses and site sketches however allow for geographical analysis using traditional mapping methods. The remaining 27 communities provide were mapped using GIS methods (ESRI ArcMap 9) in order to graphically represent the results of this research.

It is difficult to draw correlations between distance from potential source points and the prevalence of contamination for the following reasons.

1. The sampling conducted as part of this research was targeted and not random, therefore, actual rates for the entire community are not reflected in the findings. The familiarity of the facilitators with the local community and its history of asbestos use and proximity to other source points influenced the selection of surveyed sites. Samples collected within each surveyed site were randomly selected.
2. The mapping used to estimate the geographic location of the original potential source points (mines, tailings dumps and mills) is not accurate in all cases and many other source points were identified during the community surveys which were not represented by the DME supplied database. Therefore, the actual distance from source to receptor may not be accurately represented on the maps used in the analysis. Additionally, representing a source point (as is shown on the DME RPI database) is an inaccurate representation of the conditions on the ground. The mine adits, tailings dumps and stockpiles all often located over areas of several square kilometres and therefore using a somewhat arbitrary centre point from which

to make distance measurements is problematic. This was accounted for by using the one kilometre buffer from the DMME data point as the normalized mine footprint. Along these lines the communities themselves are somewhat amorphous and not conducive to specific points of measurement.

The most significant find of this aspect is that even at the communities furthest from the likely source point there is still considerable contamination present. The linear regression of the community contamination rates versus distance does indicate a decreasing rate of contamination correlated to distance from the source (see Figure 5.9). This finding is consistent with that of Felix (1997) in the Ga-Mafefe communities.

It has been previously documented by Felix (1997) and Braun et al. (2001) and by this research that much of the building materials used in construction is obtained locally and that asbestos was a preferred material to mix with soil for use in making blocks, cement, and plaster. The availability of asbestos tailings versus other source materials is then the most likely factor in its prevalence. For instance, numerous communities near dry stream beds chose to use the sand from the stream beds for local construction yet these same communities still had correspondingly high rates of contamination. The largest factor then is likely individual preference for construction materials at the availability of materials to the construction site at the time of construction.

The following table (5.9) identifies those communities with the highest rates of contamination, inclusive of all land uses surveyed, by percentage of sites identified as having either soil and/or building materials containing asbestos at trace levels or greater.

Based on the results of this research the overall rate of contamination was 73% for all land uses combined. Of the 36 communities, only two (6%) were found to contain no asbestos detected in the soil and building material samples collected at three separate locations. A total of eleven communities were reported at a contamination rate of 100% (n=62 samples). Since the sample locations were not selected on a random basis, statistical extrapolation is not possible. For this reason, one community (Ga-Mopedi) was selected as being representative of the overall Study Area conditions. A more thorough home to home survey of the community was completed as part of this research in order to test the veracity of the initial targeted survey results and to provide a higher level of confidence in statistical extrapolation to the remaining communities. This is important as one of the stated goals of this research is to map the extent and severity of contamination and thus a total quantification of the extent (i.e. number of homes, buildings, roads and open space areas that are impacted) must be determined with a reasonable level of accuracy.

Table: 5.9: Total number of sites surveyed per community and rates of contamination of soil, building materials or both

COMMUNITY	TOTAL NUMBER OF SITE SURVEYED	NUMBER OF SITES CONTAMINATED	PERCENT CONTAMINATED
Bankhara	5	1	20%
Bodulong	5	3	60%
Draghoander	3	2	67%
Groenwater	1	0	0%
Jenhaven	2	0	0%
Kathu	2	2	100%
Koegas	4	4	100%
Kuruman	15	8	53%
Owendale	1	1	100%
Prieska	21	12	57%
Wandrag	5	5	100%
Westerberg	1	1	100%
Wrenchville	18	5	28%
Batlharos	49	40	82%
Galotolo	5	5	100%
Ga-Mopedi	33	32	97%
Ga-Motsamai	11	11	100%
Heuningvlei	89	60	67%
Gasehubane	7	5	71%

COMMUNITY	TOTAL NUMBER OF SITES SURVEYED	NUMBER OF SITES CONTAMINATED	PERCENT CONTAMINATED
Maruping	24	17	71%
Masonkong	12	10	83%
Ncweng	1	1	100%
Pietboos	2	2	100%
Gateshikedi	6	3	50%
Sedibeng	19	18	95%
Seven Miles	6	4	67%
Sloja	4	3	75%
Tshukudung	8	4	50%
Tsineng	5	4	80%
Seodin	11	5	45%
Maipeng	14	13	93%
Magojaneng	18	18	100%
Mothibistad	9	1	11%
Magobing	12	12	100%
Vergenoeg	8	5	63%
Pomfret	5	3	60%
Totals (36)	**441**	**320**	**73%**

5.11. Conclusions

This chapter presents a summary of the results of the community surveys conducted as part of this research. The objective was to present in a spatial context the extent and severity of environmental asbestos contamination in the former mining regions of the Northern Cape and North West Provinces (otherwise referred to as the Study Area). The communities selected for this screening level survey were determined based on a preliminary risk ranking discussed in Chapter three as modified by the experience of the local facilitators. Following their identification, sampling of suspected land uses that represent those typical of the Study Area was completed. The sampling concentrated on soil and building materials at specific sites and all samples were subjected to the preferred laboratory method of analysis discussed in Chapter four. Due to the extensive geographic scope of this effort (36 individual communities surveyed and 441 individual sites with 1 843 individual samples analysed in the screening-level assessment. Home sites represented the largest land use segment surveyed, followed by schools then roads (in particular local dirt streets in close proximity to communities).

This research, including the sampling and analysis of 36 communities over two provinces of South Africa, represents one of the largest surveys in geographic scope conducted to date for environmental asbestos contamination. The communities represent an area of approximately 25 000 square kilometres in size. However, the sampling density is characterized as a screening-level survey only as the intensity is not sufficient to characterize any one community or site in order to determine specific risks and/or to develop site specific remediation plans.

This research has documented via a screening level assessment using scientifically valid and industry standard methods, the existence and severity of environmental contamination within the former asbestos mining regions the Northern Cape and North West Provinces of South Africa. The contamination is most prevalent within the first few kilometres surrounding the former mine, mill and dump sites with decreasing rates of contamination extending out several kilometres from the original mine sites. The extent to which the contamination extends appears to be more related to anthropogenic action than to climatologic forces. Future surveys will need to take into account the distances from the former mining sites including transportation routes and access as potential risk factors in determining where to conduct sampling and risk assessment programmes.

The results indicate that two conditions are evident. One, the survey was effective at targeting those sites suspected of containing asbestos contamination and therefore captured the majority of the extent of contamination. Results of the targeted surveys captured a much greater percentage of individual locations (all land uses) that were in fact contaminated with asbestos versus the full representative community survey. Thus, the target survey, using trained and local facilitators was an accurate method for identifying locations of contamination but was not useful in extrapolating those rates to a larger unsurveyed population. The results cannot be relied upon to represent the total extent of contamination in any one community as they were conducted at a screening level. However, they are effective at defining the approximate limits of contamination in a rapid and cost effective manner and thus are also helpful in prioritizing those communities that represent the most urgent need for follow up investigations and remediation. Rates of contamination in the detailed survey are consistent with other similar studies using differing methods (Felix 1997; REDCO 2007). However, this method provides a more useful data capture in that delineation of contaminated locations can be accomplished and the reported results are comparable to other published studies as similar laboratory methods were used by this research.

Based on the latest census data (South Africa Census 2001) there are approximately 20 933 households within the communities surveyed by this research. Using the average rate of contamination based on the detailed survey of Ga-Mopedi (25 percent) yields a total of 5 233 homes that may be contaminated with asbestos within these communities. This does not include the number of schools, roads, churches, public buildings and other land uses included in this research. Given the ubiquitous nature of the environmental contamination within many of these communities, it is in fact, the entire community population that is at risk for exposure. Many of the factors that influence risk have been reported in this Chapter such as the presence of contaminated soils, dirt covered roads, building material condition and accessibility. These are more fully assessed in Chapter 6 and a cumulative quantitative exposure assessment is presented. The individual locations are then prioritized for their relative risk and presented in Chapter 6 based on a qualitative model developed by this research.

CHAPTER 6

6. EXPOSURE ASSESSMENT FOR THE STUDY AREA

My name is Lorraine Kember. I lost my husband and partner of 37 years to pleural mesothelioma in December 2001. As a small child, my husband had lived in the asbestos mining town of Wittenoom, for a period of seven months. At the age of fifty two he began to experience shortness of breath.

Children innocently playing in their own back yard inhaled the deadly dust; they had no way of knowing that their sand was the deadly asbestos blue. A good bath at the end of the day may have removed the dust from their skin but the dust in their lungs remained and would lay dormant for many years before claiming its deadly legacy. Brian Kember was one of those children.[25]

6.1. Introduction

The previous chapters described the process by which communities were selected for site specific sampling (Chapter 3), the laboratory process used to examine the samples (Chapter 4) and the results of the sampling and analysis programme (Chapter 5). Environmental asbestos contamination was identified in 36 communities throughout the Study Area. This Chapter provides an assessment of the potential impact (measured in increased predicted mortality within the Study Area) as a result of the existence of environmental contamination identified in Chapter 5. It is based on an understanding of the relationship between environmental contamination and exposure pathways. The exposure data are based on samples collected in the Study Area as compared to activity-based sampling programmes conducted in South Africa by previous studies and more recent data gathered from the United States. The limited sampling completed as part of this research is validated by the surrogate data. Chapter 7 develops this information into a qualitative risk-based prioritization for risk reduction strategies. A risk assessment paradigm was developed based on the results of the previous chapters including the conceptual exposure model presented in this chapter.

It is important to estimate the public exposures to environmental asbestos contamination in order to predict the increased risk of asbestos related disease (specifically, lung cancer and mesothelioma). Increased disease risk above that

[25] Taken from, "Lean on Me, Cancer through a Carer's Eyes" presentation by Lorraine Kember at the Global Asbestos Congress (GAC), 2004. Tokyo, Japan. Statements used by permission of the Author.

which society deems acceptable should trigger a response in order to reduce the risk. The determination of an "acceptable" level can be subjective but it is necessary in order to inform decision-making and to establish risk-based actionable criteria. It is also important to estimate the disease burden based resulting from environmental exposures as opposed to the previous occupational exposures experienced by mine workers within the Study Area. In the absence of comprehensive epidemiological data for the Study Area it helps to place the region within the context of other locations in the world experiencing similar circumstances.

This Chapter then seeks to answer the following questions for the Study Area:

- How big is the population at risk within the Study Area?
- Given the conditions identified in Chapter 5, what are the expected exposures resulting from environmental asbestos contamination?
- Using published human health risk assessments, what are the predicted increases in mortality associated with these exposures and are they actionable based on similar circumstances identified in other countries?

6.1.1. Background to human health risk assessment

Human Health Risk Assessment (HHRA) is typically a four step process as described in Section 2.8 of this document (USNRC 1983; USEPA 2003a). With respect to this research, the *Hazard Identification* and *Dose-Response* phases of the risk assessment paradigm have been completed by others as previously noted. All three commercial varieties of asbestos are considered carcinogenic by a number of international institutions with no lower threshold of exposure considered to be safe (ATSDR 2003). A discussion of the issues surrounding dose-response relationships and fibre toxicity is provided in Chapter 2, but for the purposes of this risk assessment, the following assumptions are made:

- All commercial varieties of asbestos mined in South Africa and found within the Study Area are carcinogenic, but the amphiboles are more potent than chrysotile especially with respect to the induction of mesothelioma;

- Fibre size plays a role in the toxicity of asbestos with longer, thinner fibres being more biologically active than short fibres, though short fibres may also play a contributory role;
- There is no lower threshold of exposure that is considered safe though there may be a threshold whereby the risk of disease is within acceptable parameters to society. This chapter has utilised disease end points specific to the type of asbestos found within the Study Area and the types of analysis completed as part of the exposure assessment. Both sets of results are presented for comparison and discussion.

The amphiboles are considered to have a higher potency with respect to their carcinogenic capacity than chrysotile (Berman and Crump 1999, ATSDR 2003; Whitehouse 2008). However, this distinction only applies to one region of South Africa (Mpumalanga Province) in that the other three regions mined amphibole asbestos. The Study Area is characterized by amphibole asbestos mining (primarily crocidolite) and thus, toxicity data for amphibole specific exposures are discussed.

Exposure assessment involves describing the nature and size of the population exposed to a substance and the magnitude and duration of their exposure. The evaluation could concern past or current exposures, or exposures anticipated in the future (Batterman et al. 2000). The following questions (amended to fit this research) have been developed from various exposure assessment guidelines (USNRC 1983; EPA 1992; Berman and Crump 1999; EPA 2003b) that must be considered during the exposure assessment:

- How to estimate exposure?
- What exposure data are available and is it representative for the situation?
- Which factors that control exposure are important?

The role of exposure assessment within this research is to estimate human exposures (in terms of concentrations) and doses (in terms of fibres per millilitre (f/ml) averaged over a lifetime for the Study Area population. This is then reported as fibres per millilitre year (f/ml-year).[26] Typically, emission rates of asbestos fibres and their transport determine the concentration time profiles of exposure (MP van Veen et al. 2001). A number of exposure scenarios have been developed for asbestos, the predominant characterizations being occupational. Work in the 1970s by Mount Sinai (Dr Selikoff) established asbestos hazards by occupational groups, however, little research has been done to date to identify environmental exposure scenarios using a similar rationale (Maule et al. 2007; Magnani et al. 2000).

This research has reviewed a variety of methods and materials in order to determine the most appropriate and effective approach to an overall risk characterization of the environmentally contaminated areas of the former asbestos mining regions. The task of completing exposure assessments for secondary environmental asbestos pollution is problematic for the following reasons:

- Few field assessments of environmental exposures (expressed as airborne concentrations) in the former mining regions of South Africa were identified in the literature and many of these utilized differing collection and analysis methodologies and counting rules;
- Airborne concentrations of asbestos associated with environmental exposures are highly dependent upon the location of the asbestos, its condition, and most importantly, the types of activities that may lead to the release of fibres into the atmosphere. This research included extensive environmental sampling of potentially contaminated media (primarily soil and building materials) as these are the components that help to define the extent and severity of contamination. Resulting exposures were estimated using limited primary data collected as part of this research that validated other similar studies in South Africa and the United States;
- Electron microscopy is the preferred method of determining airborne concentrations of asbestos and large volume samples are required to meet the required sensitivities. These tests are expensive to set up and analyse and were thus not used extensively in this research.

[26] In some literature this is referred to as fibre years per milliliter (f-yrs/ml).

6.2. Methods and materials

This research chose to use other published data for similar case studies as a proxy for the environmental exposures that are likely to occur within the Study Area augmented by limited air quality analysis. The following description of the methods and materials describes the air quality sampling completed for the Study Area as part of this research. It also describes the rationale behind the selection of surrogate data used in the determination of both ambient and activity-based air quality data to be used in the quantitative exposure assessment. The selection of risk coefficients is described in sections 6.3 through 6.3.6.

A total of nine samples and four field blanks were collected during this research. All samples were collected by the author using either a Gast high volume air pump (run at 10 litres/minute) or a Gillian personal air pump (low flow run at 4 litres/minute). All pumps were calibrated using a bubble calibrator before and after sample events and were within industry tolerances (less than 10 percent). All filter cassettes were uncoated mixed cellulose ester (MCE) with an eight micron pore size. Five samples were collected to assess the ambient air quality in four locations. This research included four activity-based samples designed to validate the results of previous surveys. One sample of children playing in a contaminated schoolyard was collected (high volume area sample), one sample from inside a classroom during moderate activity (high volume area sample), and two samples from the back of a vehicle traveling along contaminated roadways (low volume personal air pumps). Sluis-Cremer and du Toit (1980), Felix (1997), Viridus Technologies (2002), and this research all measured airborne concentrations within residential areas on the amphibole fields, from dust generated by passing traffic on dirt roads and from children playing soccer. Of these, only this research used TEM/SEM for the laboratory analysis with the remaining analysed by PCM and thus the results are not quantitatively compatible. The results of these are discussed below.

Sample SA1 was collected at an un-rehabilitated tailings dump with raw fibre visible during a mild breeze (but no active disturbance) for a period of 180 minutes at a flow rate of 10 litres per minute. The sample was analysed by an independent laboratory using National Institute of Occupational Safety and Health (NIOSH) 7402 counting rules and found no reportable fibres or structures/matrices. A second sample (SA2) was collected at the Ncweng Primary School (old location with soil contamination at 1-3 percent) during non-active conditions. This sample was run at 565 litres of volume and also recorded no countable structures or fibres (analysed by the author and lab assistant at Nelson Mandela Metropolitan University Physics Lab using SEM). The same location (AB2) was sampled during active play to model bystander exposures with asbestos fibres recorded (0.003 f/ml). Sample numbers SA3 and SA4 were completed on the interior and exterior of a house identified as having contaminated building materials in poor condition and contaminated soil. The finding is below the method sensitivity of <0.0005f/ml. Sample SA5 was also a static sample that did not record asbestos fibres – it was conducted at a house within the same community with no known sources of contamination.

6.2.1. Estimation of exposure

Exposure assessment for asbestos has undergone a number of changes over the past several decades, mostly brought about the increasing sensitivity of laboratory equipment, including the resolving power of electron microscopy and its ability to distinguish fibre types. Early measurements depended upon impingers which only measured atmospheric concentrations of dust, from which, estimates of the fibre burden were then determined (Perry 2004). This method was superseded by the use of air pumps that deposited fibres onto specially configured cellulose polycarbonate filters that were then analysed by optical microscopy with a much greater resolving power. The primary drawback to this method was the inability to distinguish between asbestos fibres and other fibre types, plus the resolving power was still not sufficient to characterize the very thin fibres that are considered biologically active (Berman and Crump 1999). However, this was a standard method used in the 1960s and 1970s when a number of studies were completed to determine occupational exposures to asbestos and inhalation unit risk. Transmission (TEM) and scanning electron microscopy (SEM) are the current methods employed that overcome most of these earlier constraints. However, many studies that employ SEM or TEM have used varying fibre counting methodologies and thus the reporting of fibre concentrations are not always consistent. Therefore it is difficult to correlate studies done over varying time frames, using different sample collection and laboratory methods for analysis to establish one, generally accepted, level of environmental exposure (Bourdès et al. 2000). Furthermore, no accurate correlation exists between PCM data from which earlier occupational risk assessments were derived and the more sensitive TEM/SEM data that would allow for a straight-forward conversion. This research has presented, to the extent possible, only those studies that use either TEM or SEM (with the exception of Felix [1997] who used PCM). Results are generally reported in (or converted to) fibres per millilitre (f/ml).

6.2.2. Available exposure data that is representative of the Study Area

Previous studies (Sebestien et al. 1979; Robock et al. 1984) have documented airborne concentrations related to environmental exposure, specifically within areas of asbestos mining and waste disposal, as well as rural and urban background levels. These studies are largely based on large sample volumes collected in the outdoors as they attempt to measure the ambient concentrations of asbestos in the general atmosphere. The results range over several orders of magnitude including those specific to communities downwind of mining or mill sites. The subset of samples reported from sites identified as being from within the vicinity of mines and dumps still range over three orders of magnitude. These ambient concentrations are important considerations in the establishment of risks and they point to the necessity of remediating open sources of airborne concentrations such as asbestos waste dumps and tailings piles but they do not provide the entire range of exposure scenarios that are possible within the affected populations.

Recent investigations of environmental contamination from asbestos pollution in the United States are analogous in many respects to the conditions within the Study Area. El Dorado Hills, California, Ambler, Alaska, Clear Creek Management Area, California and Lowell, Vermont are regions with naturally occurring amphibole asbestos in the ultramafic rock strata. Within these areas the material has also been disturbed and utilised for local construction, as road fill and is now a contaminant of concern. Libby, Montana is another region in the U.S. where vermiculite contaminated by amphibole asbestos was mined and processed. The surrounding community is substantially contaminated with asbestos in the building material and soil. Ambient air monitoring has been completed in both of these areas to determine background concentrations of fibres (Section 6.3.2). The analysis has included TEM (using a variety of counting rules) so that the results can be compared to risk assessment models more recently developed for amphiboles. The current research in South Africa completed limited air sampling (static and activity-based) in an effort to establish the ambient air quality in the Study Area and as a comparison to other similarly-based investigations in South Africa and the United States.

There is a dearth of data on environmental exposures, but some scenario-based and activity-based sampling has been completed. Within South Africa, the only activity-based sampling of environmental contamination that was identified was conducted by Felix (1997), Sluis-Cremer and du Toit (1980), Viridius (2002), and as part of this research. The results of limited airborne sampling conducted as part of this research are used to validate the previously published studies from South Africa and as a comparative model to the more recent activity-based sampling completed by the U.S. EPA at various locations in the United States.

6.2.3. Important factors that control exposure

Ambient concentrations of asbestos in the atmosphere are relevant to an establishment of baseline conditions. However, just as in the occupational setting, various activities will lead to varying rates of airborne concentrations of asbestos fibres. Additionally the condition of the asbestos building materials (friability, accessibility, damage, etc) and the soils (vegetative cover, moisture content, humidity, wind speed, direction and duration, along with perhaps other unaccounted for factors) may also influence fibre entrainment. Therefore, salient factors included in this risk assessment include the following:

- Type of material
- Condition of material
- Soil Cover

- Land use (as a proxy for activities that may occur within the area of contamination)
- Accessibility of the material
- Types of activities that may lead to exposure (this topic is addressed in greater detail in Chapter 7).

The measured dose of asbestos fibre concentration from similar conditions can vary by several orders of magnitude depending upon the sample collection method, laboratory method and sensitivity, whether the sample is collected under static conditions or through aggressive techniques (such as using a leaf blower to generate airborne dust), (Miller 2008). For occupational settings, concentrations are generally averaged over a short duration (such as short-term exposure limit) or an eight hour work day (referred to as a time weighted average). These are typically reported in order to be consistent with an occupational standard. For environmental exposures, the background concentration of asbestos fibres is that amount that humans are likely being exposed to continuously over their entire lifetime. This exposure level will result in a background rate of disease within the affected population. However, within the context of the Study Area, more specific activity-based exposure is likely to yield considerably higher concentrations of exposure, albeit with a much shorter duration per event, but, given the frequency of the event, the overall exposures (lifetime) may still be relatively high. This research established lifetime exposure scenarios based on a combination of ambient and activity-based sampling within the Study Area and within other regions based on a literature review.

6.3. Methods for exposure assessment for environmental asbestos contamination

This research has developed a seven step process to estimate the human exposures to environmental asbestos contamination within the Study Area. The seven steps are as follows:

1. Determine exposure cohorts based on age and typical activity scenarios for the Study Area population.

2. Establish likely ambient air concentrations using the results of field investigations completed as part of this research augmented by published studies within settings similar to that of the Study Area.
3. Establish activity-based exposures assuming typical activities corresponding to the age cohorts identified in Step 1 and based on the land uses and condition of the contaminated sites within the Study Area.
4. Develop a cumulative exposure for the entire Study Area population.
5. Apply risk coefficients related to the fibre type and laboratory method to the calculated cumulative exposure rates to the Study Area population.
6. Compare the results to similar published studies including the results from the Ga-Mopedi survey data prepared as part of this research.
7. Discuss the strengths and weaknesses of this approach.

6.3.1. Determine exposure cohorts based on age and typical activity scenarios for the Study Area population

This research identified cohorts based upon typical exposure scenarios that can be anticipated for each age group. Exposed populations were determined using the following method. Locations of the contaminated communities (n=27) identified in Chapter 5 were plotted using GIS and overlain with the Ward boundaries per the South African Explorer GIS dataset (South Africa Census 2001). Those Wards within a 10 kilometre radius of a contaminated community were queried for data on population (see Figure 6.1). Some Wards extend beyond the 10 kilometre radius therefore populations are not exclusive to the ten kilometre boundary. Additionally, as described in Chapter five, some locations of contamination extended beyond the 10 kilometre radius and thus using the total Ward population was considered a reasonable approximation of the current potentially exposed population. Where Ward data were not available, Tribal Authority population data was used (Census 2001). A total of 17 Wards representing the 27 communities were identified in Chapter 5 (see Figure 6.1). The population totals that correspond to the exposure scenarios are as follows:

Table 6.1: Ward population data (based on South Africa Stats 2001)

AGE COHORT	POPULATION SIZE IN STUDY AREA
0-4 Years:	16 610
5-19 Years	47 807
20-64 Years	55 327
>65 Years	5 451 (assumed to be 64-70 years of age for model purposes)
Unknown	935
Total:	126 130

Age cohorts were defined based on ages that represented differing exposure potentials and that corresponded with the classifications provided in the census data (Census 2001). The classifications were allocated as follows:

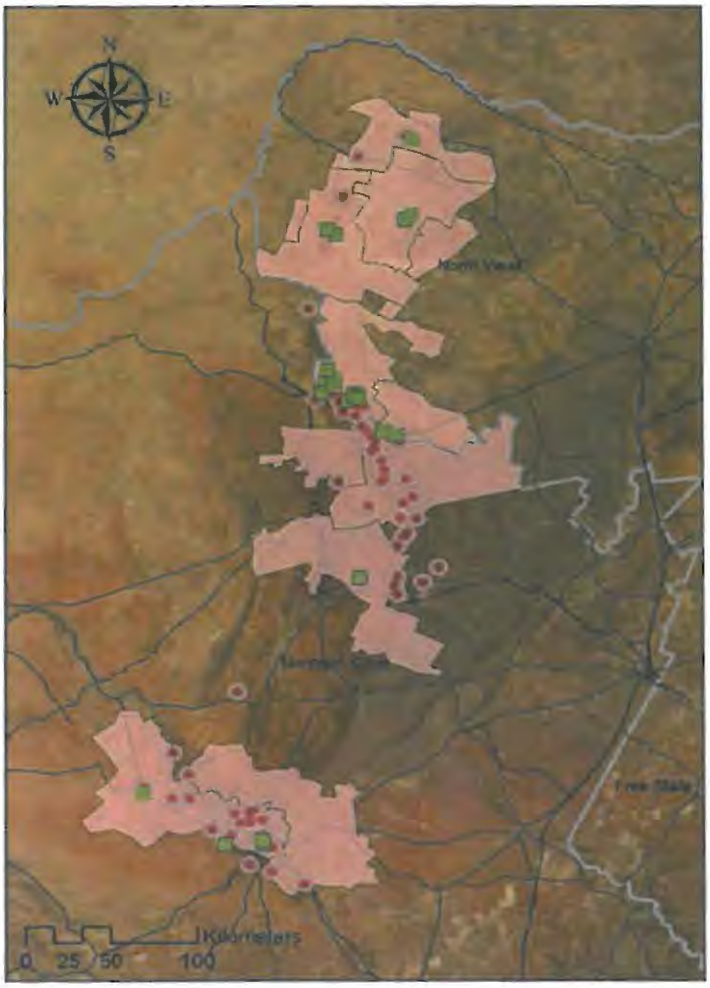
Ages 0 through 4 years / 4 years of exposure

Rationale:

Pre-school age children play on the ground thus they are closer to contaminated soil, one of the potential sources of exposure identified in Chapter 5. They also engage in open-mouth breathing while playing. This potentially creates less restriction in the airways thus allowing larger diameter fibres to be inhaled deeper into the lung. The age of first exposure is a primary consideration with respect to susceptibility for ARD (ATSDR 2003).

Exposure Profile:

Pre-school age children sleep more than adults and therefore have an increased period of inactivity. However, active periods are more aggressive than adults. Active and Passive exposures are therefore equal. Within the Study Area the total population of naught to four years olds is 16 610.



Legend

Communities Surveyed

Main Road

Study Area Wards and Tribal

Figure 6.1: Map of Study Area Wards

Ages 5 through 19 years / 15 years of exposure

Rationale:

School age children actively play on exposed or partially exposed soil such as playgrounds and football fields. They also spend time walking to and from school and within their communities along mostly dirt roads with copious amounts of dust during windy conditions and/or as vehicles pass. Herding and tending to livestock also increases exposure to dust. Passive times may be spent reading, watching television or tending to domestic chores.

Exposure Profile:

School age children sleep slightly more than adults and therefore have only a slight increased period of inactivity. However, active periods are generally more aggressive than for adults, with children of this age group also engaging in open-mouthed breathing. Active periods are therefore assumed to be greater than Passive exposures. The total estimated exposed population of this age group within the Study Area is 47 807.

Ages 20 through 64 years / 45 years of exposure

Rationale:

Adults may be exposed to asbestos in both their working and non-working hours with certain occupational fields potentially being exposed at much higher levels. Construction workers, auto mechanics, plumbers, electricians, cement workers, etc all have an increased risk due to the potential for asbestos containing products and building materials within their work places. No field data on occupational exposures were collected by this research and existing data from other countries may not be applicable to the settings within the Study Area. For these reasons, occupational exposures were assumed to be no greater than generalized passive or active exposures for this cohort. However, normal activities such as removing asbestos cement roofing, applying or removing asbestos contaminated plaster, digging in or sweeping asbestos contaminated soils, housecleaning, etc are typical activities for which most adults will engage in on a routine basis and are therefore included in this exposure assessment.

Exposure Profile:

Adults of this age group are likely to have an almost equal split between active and passive activities on a daily basis though some activities may not be as aggressive as the younger populations. The total estimated exposed population within the Study Area is 55 327.

Ages 65 and greater (assumed to be through 70 years) = 5 years of exposure

Rationale:

Older adults are considered in this research to be more sedentary and thus their passive exposure periods will be greater than active. Active times may be spent working in the garden, walking or on household chores. Passive times may be spent reading, watching television or tending to small children.

Exposure Profile:

Older adults have longer periods of inactivity and active periods are shorter in duration than the other cohorts. The total estimated exposed population within the Study Area is estimated to be 5 451. This estimate may understate the actual exposure period as the data are listed for the age >65 with no upper bound. The upper bound has been arbitrarily set at 70 for the purposes of establishing exposure duration. The average lifespan for a South African male (from birth) is 49.3 (U.N. 2005-2010 average).

6.3.2. Establish likely ambient air concentrations

Table 6.2 lists selected studies of ambient air concentrations of asbestos within urban and rural environments. The concentration of asbestos fibres (with lengths ≥5 µm) in urban and rural ambient air typically ranges from 0.0001 or 0.00001 fibre/ml, respectively (ATSDR 2001). However, as demonstrated by the results presented in Table 6.2 these results vary widely depending upon confounding circumstances such as distances from potential sources (mines, mills, asbestos factories, and naturally occurring asbestos) and emission rates. This research has identified seven studies that are consistent in their approach, reporting methods and most closely approximate the conditions within South Africa. Four of these were used in this research as a comparison to the field results of air samples collected in the Study Area. Three ambient air concentration studies are reported in the literature for South Africa (Felix 1997; Selles et al. 1984; Sluis-Cremer and du Toit 1980), of which, only one is used below to estimate ambient conditions. Other studies have reported sampling results for South Africa (Sluis-Cremer and du Toit 1980) and the asbestos mining regions of Canada (Sebestien et al. 1986) but these studies were not used in the exposure assessment model due to their differing methodologies and the fact that they were determined during mining operations and thus may over estimate current ambient exposure levels.

Table 6.2: Studies used to estimate the ambient air quality within the Study Area

Author / Location	Date	Analysis Method	Results
Felix / Mafefe, South Africa (Limpopo Province)	1997	PCM	0.0145 f/ml
Sebastien et al. / Great Britain	1996	TEM	0.0004 f/ml
US EPA / El Dorado Hills, California	2004	TEM (reported as PCME)†	0.00018 f/ml
U.S. EPA / Libby, Montana	2006	TEM (reported as PCME)	0.00026 f/ml
Average for PCM and PCME			0.00498 (s.d.=0.00825)
Average for TEM and PCME			0.00028 (s.d.=0.00011)

† PCME – phase contrast microscopy equivalent (only fibres meeting the PCM counting rules were reported)

Ambient air concentrations were reported by Felix (1997) for the Mafefe area (Limpopo Province) as 0.0145f/ml >5 μm in length (s.d. = 13.9, n = 44) following the closure of mining operations in the region. These results are reported for areas with visible asbestos contamination though specific sample locations are not provided. The presence of significant asbestos contamination in Mafefe was confirmed by the author (DEAT 2006). This level was at least two orders of magnitude higher than more recent studies in other regions and was determined using PCM methods. These levels represent (at least qualitatively) a high level of ambient exposures, only one degree of magnitude below current occupational standards (0.2 f/ml TWA South African OEL).

The second study was conducted in the vicinity of asbestos waste dumps in Great Britain (Sebastien et al. 1986 as reported by the Institut National de Santé Publique 2003). The existence of asbestos tailings dumps within the Study Area was confirmed (see Chapter 5) and therefore the Sebastien et al. (1986) results have relevance for the determination of an accurate ambient air concentration in the Study Area. However, the type of dumps and their similarities to tailings dumps (versus waste dumps) was not determined. Asbestos tailings have been reported to be a major contributor to airborne concentrations with ambient air concentrations of 10 to 10,000 times greater than background levels (Lajoie 2003). TEM was used as the method of laboratory analysis however the specific counting rules were not provided. Using a conversion factor of 2,000 f/ml per 1 mg/m³ (ATSDR 2001) yielded an ambient average concentration of 0.0004f/ml. Given the similarity between the sampling environments (existence of tailings and waste dumps) to the Study Area and the use of TEM analytical methods, it was assumed that this air concentration could be representative of the Study Area (other factors notwithstanding).

Recent ambient air quality monitoring has been completed within areas confirmed to contain environmental asbestos contamination. El Dorado Hills, California (study number 5) and Libby, Montana (study number 6) both represent conditions analogous to the Study Area. Both have widespread areas of low to moderate soil contamination with asbestos and in Libby considerable amounts of asbestos containing building material (predominantly asbestos contaminated insulation). Ambient air monitoring has been conducted using TEM analysis with PCME counting rules (for comparison to risk models). Ambient air levels in El Dorado Hills were recorded at 0.00081f/ml (USEPA 2005) and in Libby at 0.00026f/ml (USEPA 2007).

Combining the selected ambient air concentrations provided a useful benchmark for establishing a background level of asbestos air concentration in the Study Area. It is important to note that this benchmark is an approximation as to the current airborne concentrations of asbestos that the general population within the Study Area has been and is being exposed to on a continuous basis. This level will fluctuate with a variety of determinants such as proximity to source, condition of asbestos containing material and climatological factors (Singh and Thouez 1985).

Selles et al. (1984) as reported by the WHO (1986) reported average residential ambient air concentrations in the vicinity of South African asbestos mines of 0.0004f/ml by SEM. Levels close to open tailings dumps were reported to be 0.6f/ml. Ambient air levels within residences of mine workers averaged 0.0061f/ml giving a range of four orders of magnitude within one study. Reported fibres are longer than 5 µm but no information is provided as to the sample volumes, counting methods or specific sample locations (such as proximity to mine sites). The time frame of the study would have potentially been during mining and thus levels may have been influenced by these operations. However, SEM provides a reliable level of sensitivity and it is consistent with current exposure assessment methodology employed in this research.

Lebel (1997) conducted testing in the asbestos (chrysotile) mining regions of Canada. Ambient air quality monitoring for asbestos concentrations has been completed consistently since 1973, however, only since 1982 has TEM been used as the laboratory method of analysis. Results have shown a continual decline in overall levels of asbestos with the 1996 mean concentration of 0.002f/ml (Lebel 1997). A series of high volume samples collected in 1997 within three mining towns (Asbestos, Thetford Mines and Black Lake) of Quebec, Canada were also considered. The results were 0.004f/ml, 0.004f/ml and 0.007f/ml respectively with an average for all three towns of 0.005f/ml (Lebel 1997). It is important to note that these levels were recorded during mining operations and thus they may not be reflective of the current Study Area conditions since mining of asbestos has now ceased. More recent sampling was conducted in the same region (Mariner 2007) and found outdoor levels of 0.0004f/ml in ambient air greater than 1 kilometre from the asbestos mine. These results were not used in the determination of the ambient conditions for the Study Area.

6.3.3. Establish activity-based exposures

A major problem with applying an ambient level of air pollution to a risk assessment model is that it does not adequately characterize all of the situations that a person is likely to encounter, especially within a contaminated environment such as the Study Area. Whereas there are a multitude of studies demonstrating various occupational exposure settings there are very few that demonstrate the types of exposures one may encounter in a non-occupational setting. Periods of activity will greatly increase exposures, albeit for shorter durations, however the more contaminated the environment the more frequent and intensive the exposures. This research, through an extensive literature search and on-site sampling has developed an exposure index based on life-cycle activities that may more accurately reflect real conditions. This index is based on the following assumptions:

1. People at various stages in life (based on age) are likely to be exposed to environmental pollutants in different ways.
2. Activities may be broadly grouped into categories of "active" or "passive" based on their potential to generate dust and that generating dust within the contaminated portions of the Study Area will lead to an increase above the ambient background level of respirable asbestos fibre. The types of active and passive activities will generate a wide range of exposures but these can be averaged and time weighted to determine a lifetime exposure estimate.
3. By completing a time weighted average (TWA) for the various active versus passive activities, by age group, a more realistic yet still generalized exposure matrix is generated that can then be applied to a risk coefficient to estimate increased mortality resulting from lung cancer and mesothelioma for the Study Area population.

A total of fifteen studies (Table 6.3) were reviewed as part of this research to determine the types of activities and their resulting exposures that may be expected within the Study Area population. While only four of these studies reported results for South Africa (three of the four were conducted within the Study Area), they augmented samples collected by the author as part of this research. The studies represented in Table 6.3 comprised of both personal air samples (those with an air pump attached to the individual and a collecting filter within the individual's breathing zone) and area samples (those stationary sample points with typically higher air volumes designed to determine the fibre concentrations within the immediate environment. Additionally, the laboratory detection methods differ for results reported by Felix (1997), Viridus (2002), Sawyer and Spooner (1979) and Sluis-Cremer and du Toit (1980) and are thus not directly comparable.

In order to simplify the application of these various studies into a cumulative exposure assessment model, the results have been categorized into Indoor and Outdoor Passive and Indoor and Outdoor Active exposure scenarios. The rationale being as follows:

Indoor Passive: Indoor passive results are described as the arithmetic mean of individual studies (weighted averages based on sample size) and studies that represent activities such as routine tasks such as indoor building (and office) with ACBM (HEI 1991), teaching/attending school (Felix 1997), routine activity at home (USEPA 2007), and results from this research (Ga-Mopedi).

Indoor Active: These studies represent indoor activities that may generate dust within the residence or work environment resulting from the presence of asbestos containing building materials. These results do not include occupational exposures resulting from working with asbestos as part of an asbestos industry (such as mining, milling, asbestos cement manufacturing, etc) as these industries are not within the Study Area. Incidental exposures to workers/residents within the Study Area such as brake mechanics, construction workers, etc., were not assessed.

Outdoor Passive: Outdoor passive studies represent exposures that may occur as a result of being outdoors within an environment that is contaminated with asbestos. For the purposes of this research, the ambient concentrations predicted for the Study Area are used for this exposure scenario and combined.

Outdoor Active: These studies represent active work or play in an outdoor area of known or suspected environmental contamination by asbestos. This includes walking along a contaminated road and being subjected to dust generated by passing traffic (Sluis-Cremer and du Toit 1980, Viridius 2002), working in the garden (Felix 1997; USEPA 2001, 2006; ATSDR 2006, 2007b, 2008) and outdoor recreation (USEPA 2005). Photo 6.1 is an example of dust generated along a contaminated road within the Study Area by a passing vehicle in the proximity of a residential community.

Table 6.3: Studies used to characterise personal exposures to environmental asbestos contamination

Author / Location	Date	Analysis Method	Activities Modelled
US EPA – Libby, MT	2001	TEM	▪ Working in soil ▪ Routine house activity ▪ Active house cleaning
US EPA – El Dorado Hills, CA	2006	TEM	▪ Children playing outside ▪ Adults recreating outside ▪ Outside active work
ATSDR – Ambler, Alaska	2007b	TEM	▪ Riding 4-wheelers on contaminated dirt roads
ATSDR – Oak Ridge	2006	TEM	▪ Recreating ▪ Observation of recreational activities
US EPA – Clear Creek	2008	TEM	▪ Shovelling soil
Fowler	2000	TEM	▪ Sawing through ACBM
Felix	1997	PCM	▪ Various outdoor labour tasks ▪ Children playing ▪ Routine house cleaning ▪ Teaching and attending school ▪ Herding ▪ Gardening ▪ Normal walking in the community
Viridus Technologies – Northern Cape Road Study	2002	PCM	▪ Walking along side of a dirt road with passing traffic
Lange et al.	1996	TEM	▪ Removing ACBM cement sheets
Mlynarek et al.	1996	TEM	▪ Working in an office with ACM
Lee et al.	1992	TEM	▪ Inside and outside a building with ACM
Viallat et al. – Corsica NOA	1991	TEM	▪ Buildings with ACM and normal activities
Sebastien	1979	TEM	▪ Inside a building with ACM and normal activities
Nicholson et al.	1979	TEM	▪ Sweeping and housework
Sawyer and Spooner	1979	PCM	▪ Sweeping and dusting

Photo 6.1: Contaminated dust generated along a dirt road by a passing vehicle in Ga-Mampa – village is to the right of the photo with homes 10 metres +/- from road (photo by Author)

6.3.4. Develop a cumulative exposure for the entire Study Area population

This research has averaged the exposure studies from other locations for comparative analysis to the findings of this research. These other studies represent a significant body of work comprising over two thousand discrete samples. They have been separated by laboratory methodology due to the differing unit risk factors that can be applied for comparison. The mean concentrations by activity and by laboratory methodology are presented in Tables 6.3 through 6.8.

Table 6.4: Indoor active by PCM

Activity	Author	Number of Samples	Mean f/ml	Highest Reading f/ml
Housework	Felix	16	0.0086	0.027
Sweeping	Sawyer & Spooner	1	1.6	Unreported
Dusting	Sawyer & Spooner	1	4	Unreported
Laundry	Sawyer & Spooner Felix	1 4	0.4 0.0067	Unreported 0.012
Teaching	Felix	5	0.0125	0.033
Attending School	Felix	9	0.0132	0.04
Shopkeeping	Felix	8	0.0079	0.012
Totals (all samples)		**45**	**0.1478**[(1)]	

[1)] Weighted average of all reported samples

Table 6.5: Indoor active by TEM

Activity	Author	Number of Samples	Mean f/ml	Highest Reading f/ml
Housework	Nicholson et al.	1	0.0006	Unreported
Housework (active)	EPA-Libby	26	0.010	0.013
Sweeping	Nicholson et al.	1	0.0013	Unreported
Sawing ACM	Fowler	1	12.9	Unreported
Removing ACM	Lange	1	0.077	Unreported
Home – Active	Sebastien	3	0.00048	0.00075
Totals TEM (all)		33	0.401	
Totals TEM (Without Fowler)		**32**	**0.011**[(1)]	

[(1)] Weighted average for all reported samples except Fowler

Table 6.6: Indoor passive by TEM

Activity	Author	Number of Samples	Mean f/ml	Highest Reading f/ml
Indoor w/damaged ACBM – various public bldgs.	Chesson et al.	37	0.00073	Unreported
Indoor w/ACBM	Lee	1	0.0008	Unreported
Indoor (schools, homes & offices) – routine activities	HEI-AR Mylnarek et al. EPA Libby	1,377 1 5	0.00027 0.0091 0.035	Unreported Unreported 0.048
Indoors w/NOA	Viallat et al.	10	0.0297	0.182
Totals TEM Only		1,431	0.00062(1)	

(1) Weighted average for all reported samples

Table 6.7: Indoor passive by PCM

Activity	Author	Number of Samples	Mean f/ml	Highest Reading f/ml
Indoor	Sluis-Cremer & Du Toit	614	0.03(1)	4.12

(1) Weighted average for all reported samples

Table 6.8: Outdoor active by TEM

Activity	Author	Number of Samples	Mean f/ml	Highest Reading f/ml
Gardening	EPA – Libby EPA – Swift Creek EPA – Swift Creek	1 6 6	0.066 0.018 0.078	Unreported Unreported Unreported
Children & adults recreating or observing	EPA – El Dorado EPA – El Dorado ATSDR – Oak Ridge EPA – Swift Creek	240 32 ? 6	0.0077 0.008 0.1023 0.029	0.11 0.02 Unreported Unreported
Riding in an open vehicle on dirt roads	ATSDR – Ambler EPA – Clear Creek	6 80	0.212 0.282	>0.212 2.039
Totals		>377	0.0604	2.039
Totals TEM Only			**0.0628**[1]	

[1] Weighted average for all reported samples

Table 6.9: Outdoor active by PCM

Activity	Author	Number of Samples	Mean f/ml	Highest Reading f/ml
Gardening	Felix	7	0.015	0.041
Children recreating	Felix	13	0.0203	0.09
Walking in community/along a contaminated road	Felix Kgalagadi Road Study	9 139	0.012 0.52	0.09 Unreported
Collecting wood	Felix / PCM	3	0.0074	0.008
Loading river sand	Felix / PCM	2	0.008	0.012
Herding livestock	Felix / PCM	4	0.0065	0.011
Building / Fencing	Felix / PCM	10	0.0138[1]	0.031
Totals				

[1] Weighted average for all reported samples

The determination of a cumulative exposure level is based on the following formula:

Exposure = $\sum$(TWF)*(Exposure Rate [f/ml])

Where: TWF = (Age specific scenario in hours/day)/24 • (365 days/year) • (age specific years/75) *Exposure Rate is expressed (or converted to) fibres per millilitre (f/ml)*

Source: Adapted from ATSDR (2007) and USEPA (2001)

6.3.5. Determination of cumulative lifetime exposures and application of risk estimates to the Study Area population

This research uses age class cohorts to estimate the amount of time spent engaged in various activities. For example, children ages 0-4 will engage in different activities (passive and active) and for different amounts of time than older individuals. Thus this step involved estimating total lifetime exposures based on assumptions of how much time is spent engaged in either passive or active type activities for different age cohorts. For example, over the course of the period from ages 5 through 19 (15 years) an individual is estimated to spend a total of four hours per day engaged in active behaviour in outdoor conditions. This includes walking to and from school, recreating and/or working outdoors. Over a 70 year lifetime this equates to 3.5 percent of the individual's life (see Table 6.11). Specific excess risks for lung cancer and mesothelioma were calculated as the time-weighted factor (TWF) of airborne concentration (f/ml) multiplied by the Unit Risk multiplied by the age specific population cohort related to the exposure scenario. This is expressed as:

Age Class Cohort Specific Excess Risk is equal to: C*TWF*R*P

Where C (airborne Concentration)

TWF is equal to the age specific activity time weighted factor

R is equal to the unit Risk per method, and

P is equal to the age specific cohort population for the Study Area (source: adapted from USEPA and ATSDR)

The results of the cumulative exposure assessment are applied to the potentially exposed population within the Study Area using three different unit risk values based on the type of data reported (PCM, PCMe or TEM).

The EPA Integrated Risk Information System (IRIS) Unit Risk value of 0.23 was applied against PCM derived data. This research then applied the most recent draft protocol developed for the US EPA (Berman and Crump 2003) using only SEM/TEM derived data (per the recommendations of the methodology). The field sampling conducted as part of this research confirmed the value of using surrogate data to model approximate environmental exposures. This research then applied the most recent draft protocol developed for the US EPA (Berman and Crump 2003) for amphiboles (Conservative Model – Male, Non-Smokers) and reduced the concentration variable by 23.5% to account for only those fibres greater than 10 µm in length and less than 0.5 µm width) which is consistent with the findings of Shedd (1985).

6.3.6. Confirmation of veracity of results

Chapters 1 and 2 have discussed the lack of epidemiological data for asbestos related disease in the South Africa as a whole, and for the environmentally exposed populations in particular. The limited data available are contrasted to these findings and discussed in Section 6.5 below. In addition, the results of this hypothetical cumulative exposure assessment are also tested against the data collected as part of this research in the community of Ga-Mopedi and against unpublished data collected in Heuningvlei and Gaenesa (Dr Odendaal 2009 pers. Comm. 8 April).

6.4. Results

6.4.1. Results of static and activity-based sampling

There is very limited data available within South Africa from which to draw specific conclusions regarding environmental exposures to the general population. This research has collected field data that are specific to the Study Area and that can be used as a comparative model to other published studies using similar methodologies. A total of five static samples were collected at locations within the Study Area designed to simulate ambient environmental conditions with no active disturbance of the contaminated media. The static samples did not identify reportable asbestos fibres during a period of inactivity however, the interior sample did contain one visible crocidolite fibre greater than >5 um in length and <10 um in length and <1um in width. Tables 6.9 and 6.10 provide the results of static and activity-based air samples collected in the Study Area. All samples were determined to be below quantification limits using the specified methodologies. These results confirm the supposition that a leading agent of environmental exposure is the ability to disturb asbestos contaminated media.

Activity-based sampling efforts by others (Felix 1997) within South Africa were reviewed to determine where data gaps existed for routine behaviours within the Study Area. One major activity was the concern for riding in the back of open bakkies (trucks) along dirt roads. Copious amounts of dust are generated by these activities. Air sampling along the sides of dirt roads was completed in the Northern Cape (Viridus 2002) but the analysis was done using PCM. Similar sampling was completed in the U.S.A. by the EPA at Clear Creek and Ambler but using TEM analysis. The current research involved taking two samples (AB1 and AB2) along roads known to be contaminated in the community of Heuningvlei. Both samples indicated positive results for asbestos exposure using SEM analysis that is similar to the results reported in the U.S. studies.

The field samples completed as part of this research show good agreement with the published reports for similarly related activities using similar laboratory and counting methods (see Table 6.10).

Table 6.10: Air sample results for the Study Area

Location		No of samples	Laboratory method	Results
Static samples				
SA1	Top of tailings pile a Wandrag	1	TEM (NIOSH 7402)	<0.0005 f/ml
SA2	Ncweng Primary School	1	SEM (Modified ISO 10312)	<0.0005 f/ml
SA3-4	Inside and Outside House #4 (Ga-Mopedi)	2	SEM (Modified ISO 10312)	<0.0005 f/ml
SA5	Ga-Mopedi House #3	1	SEM (Modified ISO 10312)	<0.0005 f/ml
Activity-based samples				
AB1-2	Back of vehicle along a contaminated road (Heuningvlei)	2	SEM (Modified ISO 10312)	0.0489 f/ml 0.005 f/ml
AB3	Ncweng Primary Schoolyard – active play	1	SEM (Modified ISO 10312)	0.003 f/ml
AB4	Ncweng Primary School Classroom – moderate activity	1	SEM (Modified ISO 10312)	<0.005 f/ml

Table 6.11: Comparison of activity-based results to comparative studies (SEM/TEM data only)

Activity	Research results	Comparative studies
Schoolyard active play	0.003 f/ml	0.008 f/ml (El Dorado)
Indoor routine (residence)	<0.005 f/ml*	0.035 f/ml (Libby)
Back of vehicle along road	Mean = 0.03 f/ml High = 0.05 f/ml	0.30 f/ml (Ambler, Clear Creek, Swift Creek) High = 0.56 (Clear Creek)

* 1 asbestos fibre detected on filter media (50 fields scanned): results were lower than the reportable limit for the method

6.4.2. Results of cumulative exposure estimates

This research utilised data collected in the Study Area as well as surrogate data from other activity-based sampling by others both within South Africa as well as the USA. Table 6.11 shows the results of the cumulative exposure model developed for the Study Area. The sum of the C_{TW} is the cumulative lifetime environmental exposure. Two models were developed for this methodology. The first is based on historical data derived from PCM analysis only and a second based on TEM and SEM data. The cumulative environmental exposure was then multiplied by the method appropriate inhalation unit risk factor. For PCM derived data, the US EPA IRIS database risk factor of 0.23 is used. For the TEM/SEM derived data the proposed Berman and Crump (2003) model was used to calculate excess mortality from combined asbestos related lung cancer and mesothelioma. Table 6.11 is an example of the application using the US EPA IRIS (1986b) Unit Risk for PCM derived data.

Table 6.12: Example of risk assessment using US EPA risk factor

Model run for PCM results only

SCENARIO	TWF	Mean Concentration (f/ml)	f/ml-yr	Unit Risk	Risk	Pop	Total Excess Mortality
0-4 Outdoor Active	0.0048	0.3227	0.00154	0.23	0.000353		
0-4 Outdoor Passive	0.0143	0.0120	0.00017	0.23	3.94E-05		
0-4 Indoor Active	0.0048	1.7041	0.00811	0.23	0.001866		
0-4 Indoor Passive	0.0333	0.0082	0.00027	0.23	6.29E-05		
5-19 Outdoor Active	0.0357	0.1132	0.00404	0.23	0.00093		
5-19 Outdoor Passive	0.0357	0.0120	0.00043	0.23	9.86E-05		
5-19 Indoor Active	0.0357	1.6851	0.06018	0.23	0.013842		
5-19 Indoor Passive	0.1071	0.0082	0.00088	0.23	0.000202		
20-64 Outdoor Active	0.1071	0.1100	0.01179	0.23	0.002711		
20-64 Outdoor Passive	0.1071	0.0120	0.00129	0.23	0.000296		
20-64 Indoor Active	0.0536	1.2500	0.06696	0.23	0.015402		
20-64 Indoor Passive	0.3750	0.0082	0.00308	0.23	0.000707		
65-70 Indoor Passive	0.0714	0.0082	0.00059	0.23	0.000135		
65-70 Outdoor Passive	0.0143	0.0120	0.00017	0.23	3.94E-05		
Cumulative	1.0000	0.3761	0.1595	0.23	0.036685	126,130	4627.05

Using a Unit Risk of 0.23 (USEPA 1986), and only PCM derived data, the excess estimated mortality rate due to a lifetime of environmental asbestos exposure for the Study Area population is 4 627 or 66.1 per year (equivalent to 52.4 per year per 100 000 population). The Berman and Crump model for amphiboles, using Male Non-Smokers (combined risk for lung cancer and mesothelioma) and assuming two percent of the fibres are greater than 10μm in length, the excess mortality is 2 427 or 34.7 per year for the Study Area (27.5 per 100 000).

6.5. Discussion and conclusions

This chapter presented the development of a contextually-appropriate methodology and results based on a combination of empirical data obtained from the Study Area. Air quality sampling completed during the study yielded results that correlate with other published studies and therefore it is reasonable to assume that the cumulative exposure rates presented are an accurate estimation of the lifetime exposures to environmental asbestos contamination for the Study Area population. These results are presented as a general characterization of the Study Area in order to estimate the potential excess loss of life (total and yearly) related solely to environmental asbestos exposures that can be expected by the current population. The range for all models applied to this population for excess cancer deaths per year attributable to only environmental exposure is between 34.7 (Berman and Crump 1999) and 66.1 (USEPA by PCM). These results may very likely underestimate the current disease burden as it will be influenced by the potentially higher exposures resulting from the former mining activities and the latency period of ARD.

Using the EPA (1986) risk model for the total disease estimation is consistent with the recent regulatory approach taken at the Libby, Montana Superfund site. However, this model has been criticized for both overestimating risk (Camus et al. 1998) and underestimating risk (USEPA 2001). Whitehouse (2008) predicted mesothelioma rates of 16.6 per 100 000 per year within a ten mile (16km) radius of Libby, Montana. Marconi et al. (1989) and Magnani et al. (1991, 1995) identified 44 mesothelioma cases in an environmentally exposed population of Casale Monteferrato, Italy resulting from residing near an asbestos cement factory (average 5 cases per year in a population of ≈ 100 000). No data were reported on excess lung cancers or asbestosis. A study of three countries (Italy, Spain and Switzerland) identified an increased risk of mesothelioma in non-occupationally exposed populations living within three kilometres of asbestos cement plants (Magnani et al. 2000). In Alaska, the ATSDR (2007b) predicted a lifetime excess mortality from exposure to environmental asbestos (assuming walking 1.5 hours per day through a contaminated environment) of 120 per 100 000 (using the PCMe IRIS risk coefficient). In California the EPA estimated increased lifetime cancer rates from environmental chrysotile exposures to be between 200 and 1 000 per 100 000 exposed (USEPA 2008).

In Wittenoon, Australia a rate of 71 mesothelioma cases per 100 000 environmentally exposed population was identified at a cumulative rate of 5.5 f/ml-yr (Miller 2008). Hansen et al. (1993) identified an average of 27 mesotheliomas cases in the Wittenoon environmental cohort (n=4 659) over a fifty year period (0.54 per year) which equates to roughly 579 per 100 000 or 8.3 per year assuming a 70 year lifespan. This compares to the predicted model of 25 per 100 000 per year using the Berman and Crump (1999) risk coefficient and modelled cumulative exposures. Wittenoon produced less than two percent of the world's supply of amphibole asbestos – South Africa, 98 percent.

Within South Africa, Zwi et al. (1989) attempted to establish mesothelioma rates for the general population using a case register and found that (at that time) incidence rates were amongst the highest ever reported for a national population (over 100 per million in white males over the age of 55). The authors then go on to explain why the overall rates are likely much higher than reported in their study. One of the major drawbacks to their study (as acknowledged by the authors) is that the reporting was skewed toward whites (52% of the sample set) while it is acknowledged that blacks and coloureds likely made up as much as 90% of the workforce completing 96 percent of the dustiest job tasks (Zwi et al. 1989). Additionally, the incidence rates are not tied to ambient exposure estimates though there is an attempt to segregate between occupational and non-occupational exposures with 14.3 percent of males reporting only environmental exposure and another 11.2 percent reporting both occupational and environmental exposures to asbestos. This rate is equal to 32.9 mesothelioma cases per million population (over the age of 15) per year (or 3.3 per 100 000). Kielkowski et al. (2000) identified a rate of 277 mesotheliomas per 1 000 000 (28 per 100 000)/year in a population of environmentally exposed residents of Prieska, South Africa. This part of the Study Area was confirmed as having environmental contamination and was also a former location of an asbestos mill in the middle of the town. A study of former workers living within 100 kilometres of Kuruman in the Northern Cape showed a prevalence rate of 0.5 percent for mesothelioma with 39% of the mesothelioma cases related to environmental exposures only (Talent et al. 1980). This would equate to 1 950 cases per 100 000 exposed (28 per year). Mzelini et al. (1999) identified a 2.8 (male) and 5.4 (female) odds ratio (OR) of increased risk of lung cancer for residents of heavily polluted areas (defined as where asbestos was mined) of the Northern Province due to environmental asbestos exposures. Asbestos mining magisterial districts in the Cape Province showed increased mortality ratios (SMRs) due to asbestos exposure of almost 10 fold for all races and sexes including a predicted rate of 10 per 100 000 for asbestosis and mesothelioma within the 15-34 age group. This, along with the high rate for females points to the likelihood of environmental exposures for the resident population (Botha et al. 1986).

There is a paucity of data on cumulative lifetime exposures related to environmental asbestos contamination (Miller 2008). Those studies that have attempted to establish exposure levels have largely relied on ambient airborne concentrations reported as being typical of either "rural" or "urban" settings. However, these environmental levels contrast sharply with occupational exposures which occur over a much shorter time frame in comparison to environmental exposures. For example, environmental exposure models that attempt to predict disease rates using high volume samples conducted at stationary sites (static sampling) may significantly under estimate lifetime exposures by missing the short duration but high dosage exposures related to disturbing contaminated environmental media such as soil and local building materials. These differences in exposure are typically one order of magnitude (USEPA 2008). Furthermore, estimating disease rates over large populations or large geographic areas may miss more localized zones of heavy contamination and exposure with significantly higher rates of disease. Some work has been done to establish rates of ARD using a variety of surrogates for environmental exposure data such as production and consumption rates of asbestos per country but these are primarily related to occupational uses and thus are not transferable to environmentally exposed populations.

The predicted rate of fatal cancer (mesothelioma and lung cancer) cases (27-52 per 100 000 population per year) for the Study Area appear to be significantly higher than other reported findings reported in other regions with the exception of Talent et al. (1980) and Kielkowski et al. (2000) both of which were specifically reported for the Study Area. It may also overstate the mortality since the entire population of the Study Area Wards are not equally exposed to the full extent of contamination within their environment. It is important to review the estimated excess mortality with respect to other similar studies applied to specific environmentally contaminated regions of the world where more extensive epidemiological studies have been completed. Whitehouse (2008) reported a predicted rate of 16.6 cases per 100 000 population per year for Libby, Montana. However, while the predominant source of asbestos is amphibole, it is tremolite asbestos which is considered less carcinogenic than crocidolite. Hansen et al. (1993) reported a lower number for the environmentally exposed population of Wittenoom (also a crocidolite region) however many of the exposed individuals did not live in the contaminated region for a majority of their lives and thus may not have had the childhood exposure or duration of exposure experienced in the Study Area. Viallet et al. (1991) reported ambient levels of naturally occurring amphibole asbestos (NOA) of 0.0206 f/ml by TEM in Corsica. Applying the Berman and Crump (1999) risk coefficient for amphiboles would yield an anticipated 9.4 cases of mesothelioma per year per 100 000 population. Most significantly, using the results of the Talent et al. (1980) for the Northern Cape (environmental exposures only) and Kielkowski et al. (2000) case control study for Prieska (Northern Cape), the predicted incidence rate of 27-52 cases per year per 100 000 can be validated. Prieska is within the Study Area and confirmed by this research and a subsequent study by REDCO (2007) to be significantly environmentally contaminated. Given these concomitant findings and the inherent uncertainty of the methodology, the results of this predictive model are considered a reasonable, if not absolute, estimate of the disease burden (for lung cancer and mesothelioma) within the Study Area from environmental exposures.

This research has identified large areas of environmental contamination within the former asbestos mining regions of South Africa, in particularly within the identified Study Area. Contaminated media includes soil, building materials and road surfaces. These conditions occur within densely populated villages and communities and within very rural veld landscapes. Of particular concern however is the constant exposure of the population to high levels of asbestos contamination in their environment. This contact occurs through breathing air with ambient background levels of asbestos dust that is liberated from the soil or other surfaces through abrasion and routine activities. These activities can lead to short-term but relatively high levels of exposure during periods of significant disturbance. Taken over a lifetime, these can lead to cumulative doses of asbestos dust that lead to increased mortality from asbestos related diseases. However, there are no published studies that have attempted to define a cumulative exposure rate for the environmentally exposed populations in South Africa though studies in other regions have shown considerable increases in disease due to what are suspected as being almost exclusively environmental exposures.

The results for the Study Area indicate episodic environmental exposures are considerably higher than ambient concentrations to which the general population is exposed. By aggregating a series of activity based and static air sample results from other asbestos contaminated communities, as validated by air sampling within the Study Area, it is possible to develop a predictive model to estimate disease rates. Epidemiological studies and community health screenings are needed to verify the model predictions and to confirm or deny the anecdotal reports coming from the communities. The potential excess mortality rates identified in this research squarely place the Study Area of South Africa as having the highest rates of environmentally induced asbestos related deaths of any region in the world including Wittenoom, Australia and Libby, Montana.

This theoretical estimation of disease and excess mortality within the Study Area population resulting from environmental asbestos contamination represents a significant public health crisis. While it may be somewhat conceptual, supporting anecdotal information is consistent with these findings. These results indicate that some form of risk reduction strategies are in order for the Study Area but given the magnitude of the problem (logistically and geographically), some form of risk-based assessment is needed to prioritise the communities relative to one another.

CHAPTER 7

7. RISK ASSESSMENT MODEL AND RESULTS FOR THE STUDY AREA

"Who cares? You've got at least 192 people who died and hundreds more made ill in Libby from what has been diagnosed as asbestos-related diseases. They don't care whether it's actinolite, tremolite or buffalo-girl-won't-you-come-out-tonight. Whatever it is, it caused disease... folks in the government have got to realize it can't just be ignored"[27] *(2001).*

7.1. Introduction

Chapter 6 provided a quantitative estimation of the serious risk to the population within the Study Area due to the presence of environmental asbestos contamination. Thus there is an urgent need to remediate in order to mitigate the risk. Given the size of the Study Area and the sheer number of contaminated communities identified by this study, as well as the logistical and resource constraints of the South African government, it was determined that a risk-based method was needed to prioritise the sites and communities for remediation planning. This chapter reports on the development and application of a rapid screening model that could assist in this prioritization process. Remediation of asbestos contaminated environments can be technically, socially and financially problematic. For example, the United States EPA estimated in 2002 it would cost between U.S. $3,000 to $5,000 per house for asbestos remediation in Libby, Montana. Including additional interior cleaning and material replacement, the cost could rise to $7,000 per unit. Adding administrative costs for program implementation increased the cost to approximately $10,000 per unit. Thus administrative costs were estimated at approximately 30 percent of direct costs (EPA 2003b). By 2003 the EPA was estimating that the cost of remediation per residence was approximately $30,000. This increase was partly attributable to additional clean-up occurring in the interior attic spaces of residences. Larger commercial properties were costing upwards of $150,000 each depending upon size and degree of contamination. The rate of clean-up for residences averaged five to six per week on average with a yearly target of 250 to 300 residences

[27] Michael Beard (1940-2008), a former senior chemist for EPA for 26 years. Quoted by Andrew Schneider, www.blogseattlepi.com/secretingredients. Accessed 01 March 2008.

(assuming lost days for poor weather). The actual number of clean-ups completed on a yearly basis has been closer to 200 using on average four full time government managers and over 100 contractors. By 2008 the average cost per residential unit had risen to U.S. $ 60,000 (~R570 000) with the administrative/management costs estimated at 40 percent. However, due to the larger and more complex sites, the total average costs per site clean-up is closer to $100,000 (~R0.9 million). Project monitoring, sampling and laboratory analysis is a major component of clean-up spending. In Libby to date, approximately 100,000 samples have been collected (air, dust, soil and water) (EPA 2009).

Over the previous ten years approximately U.S. $200 million has been spent to address the Libby contamination, of which, roughly one half has been spent directly within the community. This spending does not include the health care costs for treatment of asbestos related diseases and lost revenues. Sampling costs for soil and water run between ~R950 for the basic analysis to R19 000 for more sophisticated laboratory analysis. The ramp up period for the Libby work costs as much as U.S. $25 million per year for the first three years. This period included initial medical screening of residents, administrative costs, legal costs, initial screening level sampling, testing, analysis and initial emergency clean-up activities. After the initial flurry of spending by EPA, it has since slowed down to an average of roughly U.S. $17 million per year (~R161 million).

Chapter 5 presented the results of environmental surveys that identified 36 communities as having potentially significant levels of environmental contamination from asbestos mining waste. By extrapolation the number of residential properties alone could easily number well over 6,000. It was clear that some method of quickly, efficiently and correctly assessing the exposure risks from individual locations and through aggregation of the results, the specific communities, was needed to prioritise the risk to residents. The previous chapter predicted an environmentally induced ARD burden within the Study Area as being higher than any other reported region in the world (including Libby, Montana and Wittenoom, Western Australia). The purpose of this chapter is to demonstrate the link between the environmental contamination identified in Chapter 5, the input criteria used in the conceptual exposure model presented in Chapter 6 and how the data generated by this research can then be utilised in a qualitative manner to identify those sites and communities most at risk. The results can then be used to prioritise for further assessment and remediation activities.

In order to demonstrate a link between the environmental contamination identified in the Study Area and the need for a risk-based prioritization for remediation it was considered appropriate to develop a conceptual qualitative risk assessment methodology and this forms the subject of the current chapter. It is supported by the exposure assessment described in Chapter 6 including ambient air quality and personal activity-based sampling. Qualitative criteria were developed and applied to the findings of this research (discussed in Chapter 5), in order to determine if the contamination of soils and building material is likely to generate significant human health risk at the particular locations surveyed as part of the screening level assessment.

The qualitative model was then applied to those locations surveyed within each community to determine the types and conditions of the asbestos encountered as well as the anticipated types of activities that lead to human exposures. The model was then used to determine which sites and how many are most at risk. The results can be grouped by community in order to determine those that have the highest overall quantity of high risk sites. They can then be ranked for priority for community-wide investigations and remediation planning. The model was applied to a total of 439 individual sites located in 36 communities identified based on the results of the field investigations discussed in Chapter 5.

This chapter accomplishes the following objectives:

- integrate the factors that lead to increased risk for exposure to environmental asbestos contamination into a qualitative model;
- apply the model to each site reported in the screening level community surveys in order to identify their relative individual risk; and
- map the results of the model within the Study Area by community in order to assess its implications for human exposure to environmental asbestos

contamination and where additional more detailed investigations are warranted.

7.2. Development of a Risk-Based Environmental Asbestos Model (RBEAM)

7.2.1. RBEAM inputs

This research has identified six risk factors that must be considered when evaluating the potential for environmental contamination to result in potential human exposure. These are:

1) the presence and condition of the ACM and its proclivity to release fibres;
2) the concentration of asbestos within the material assuming that the greater the quantity of fibres, the greater the airborne concentration as a result of disturbance;
3) the likelihood that it will be disturbed;
4) the existence of soil contaminated with asbestos within areas where it is likely to be disturbed;
5) the types of soil disturbing activities that may occur and how they impact upon fibre release; and
6) the potential for childhood exposure within a given location.

This model applies these criteria to determine their capacity to influence exposures to the Study Area population. The methodology developed to complete this assessment and the results of applying these criteria to the conditions identified in Chapter 5 are described in the following sections. The application of this qualitative risk assessment identifies those specific sites and conditions that may lead to the environmental exposures quantitatively discussed in Chapter 6. It was then applied to rank the communities for further assessment and remediation planning activities.

The objective was to develop a model that could be rapidly applied to large areas comprised of thousands of homes and other locations where environmental asbestos contamination is suspected or confirmed. The results of Chapter 5 demonstrated that just within the Study Area there are 36 communities where significant environmental asbestos contamination was identified. This results in thousands of homes and other sites that require a more detailed assessment to determine the specific risk to the occupants and general population. A method that can be applied using minimal training of field personnel is needed for a rapid deployment. It should be intuitive, visually based, (with the exception of the laboratory analysis) and rapidly translated into a recommendation for action if needed. The model is loosely based on those used in the United States, Australia and the U.K, but modified to allow for implementation by individuals who are not necessarily trained or experienced in environmental or occupational health sciences and to rural residential land uses.

7.2.2. Methods for application of the RBEAM

The six risk factors were combined into a conceptual risk-based environmental asbestos model (RBEAM) include:

1) The condition of the asbestos containing building material was based on data collected during the community asbestos surveys (see Chapter 5). Soil conditions were typically described as sandy with poor vegetative cover. Correlations between the age of construction and building material condition (primarily residences) were also considered and discounted during development of the model.
2) The concentration of asbestos within the building material was also based on the data collected and presented in Chapters 4 and 5.
3) The likelihood of disturbance was based on the land use of the site and the location and type of the building material.
4) The existence of soil contamination was determined based on the field sampling described in Chapter 5.
5) Soil disturbing activities were based on existing research documenting their agreement (as discussed in Chapter 6) with airborne concentrations.
6) The potential for childhood exposure was based on published research and the demographics of the Study Area.

These factors were then developed into a qualitative, conceptual risk model based on recognised exposure routes for airborne asbestos concentrations. A risk ranking paradigm (High Risk to Low Risk) was then applied to those locations surveyed as part of this research. Individual sites and communities were then ranked based on the number of High Risk sites identified. These factors were applied as steps in the development of the RBEAM.

Part 1 of the RBEAM

The RBEAM is divided into two Parts, the first with seven steps and Part 2 contains five steps. Part 1 of the model is a seven step process utilizing a decision-tree to assign an initial risk ranking (steps one though four) which is then modified based on the existence of contaminated soil and the potential for exposures to children to arrive at a final risk-based ranking. The ranking provides a qualitative assessment on individual sites where both the building and soil were assessed as part of the field work described in Chapter 5. Part 2 of the model assesses the risk from sites where only the soil was assessed. The ranking of the individual sites as average, significant or severe) can then be assessed based on geographic location, proximity to source and/or by land use. Table 7.1 depicts the first five steps of the RBEAM and Figure 7.1 graphically represents the model's decision-tree process. This model was applied to each site surveyed and the results plotted for geographic analysis. The rationale for the inclusion of these steps is explained in the following section.

Table 7.1: First five steps of the Risk-Based Environmental Asbestos Model (RBEAM) to determine the risk of ACBM to communities

ACBM LAB ANALYSIS STEP 1	ACBM CONDITION STEP 2	FIBRE RELEASE POTENTIAL ASSESSMENT STEP 3	EXPOSURE PERIOD ASSESSMENT STEP 4	INITIAL RISK CLASSIFICATIO N STEP 5
NAD	Good	NA	NA	Average
	Fair	NA	NA	Average
	Poor	NA	NA	Average
Asbestos Detected	Good	Low	Intermittent	Average
			Regular	Average
			Constant	Average
		Moderate	Intermittent	Average
			Regular	Average
			Constant	Significant
		High	Intermittent	Average
			Regular	Significant
			Constant	Significant
	Fair	Low	Intermittent	Average
			Regular	Average
			Constant	Significant
		Moderate	Intermittent	Average
			Regular	Significant
			Constant	Significant
		High	Intermittent	Significant
			Regular	Significant
			Constant	Severe
	Poor	Low	Intermittent	Average
			Regular	Significant
			Constant	Significant
		Moderate	Intermittent	Significant
			Regular	Significant
			Constant	Severe
		High	Intermittent	Significant
			Regular	Severe
			Constant	Severe

The first five steps of the RBEAM results in a potential of 30 outcomes ranging from an initial risk classification of Moderate to Severe. Steps 6 and 7 of the decision tree deal with the presence of asbestos contaminated soil and the potential for exposures to children. The initial risk classification is increased by one category for each positive finding.

7.2.3. Rationale and discussion of each step

Step 1: Confirm the presence or absence of asbestos contamination within the building material

Suspect building material should be assessed based on the preferred laboratory method identified in this research (Chapter 4). Visual assessment is acceptable for positive identification per the method described in Chapter 4 however the method is not acceptable for a finding of No Asbestos Detected (NAD). Suspect materials confirmed by microscopic analysis (referred to as laboratory analysis in the Model), are reported as Asbestos Containing Building Material (ACBM). The laboratory method will typically present asbestos concentrations as a percentage of the overall building material matrix. All other conditions being equal, the higher the concentration of asbestos within the material, the greater the potential for fibre release. The results of this research indicate that many building material samples are often contaminated at rates higher than 10 percent. Most published studies that discuss airborne concentrations of asbestos within ambient air (within buildings with asbestos containing building materials) do not mention the percentage or quantity of asbestos within the ACBM. A finding of NAD does not imply the material is completely free of asbestos fibres or residual health risk. It means that based on the limits of the methodology, no asbestos was detected. Asbestos that may be present and not identified based on the methodology is likely to be less than one percent by mass and most likely to be less than 0.25 percent.

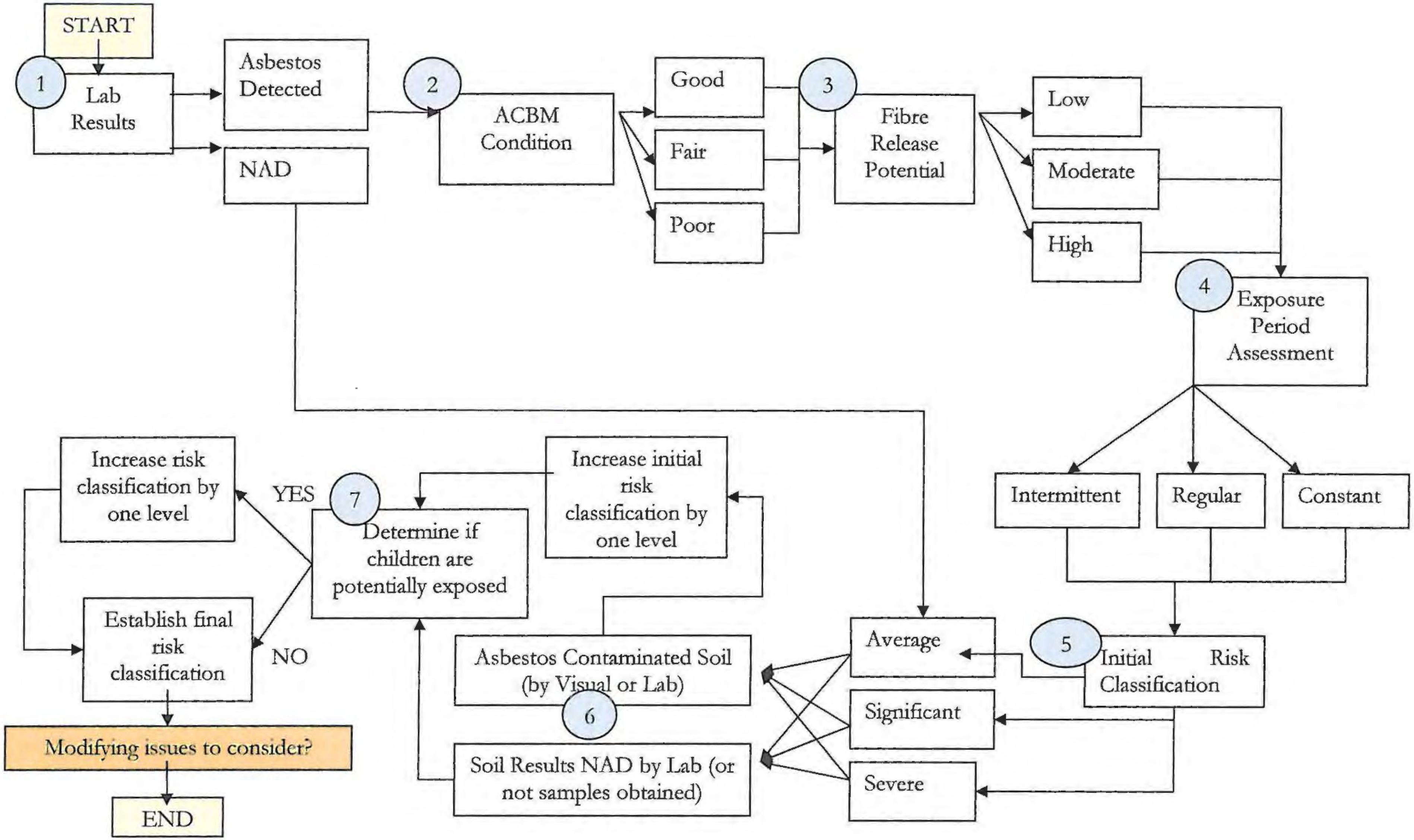


Figure 7.1: Graphic Diagram of RBEAM Decision Process

Step 2: Identify the condition of the ACBM as (Good, Fair or Poor)

The condition of the building material is important in determining its likelihood for fibre release (HEI 1991). Building material that is in poor condition (damaged, loose, uncovered, etc.) is more likely to release fibres due to either climatic (wind and rain induced erosion) or human-induced disturbances. Materials that are well maintained, coated with paint, or other forms of sealer, or are not easily accessible are less of a hazard because asbestos fibres are bound within the material rather than being released to the environment. Undisturbed ACBM is much less likely to entrain asbestos fibres if it is in a well maintained condition. Studies by Sebastien et al. (1979) and Sawyer (1991) indicate that undisturbed ACBM classified in good condition does not lead to increased risk of exposure when compared to background concentrations. These same studies indicate that ACBM in poor condition (or poorly maintained) does increase the risk of exposure. Airborne concentrations in buildings with good condition ACBM on average had lower concentrations than buildings with poor condition ACBM (in an undisturbed state). The approach used most often for determining the material's structural integrity is its "friability." The traditional definition of friability is a material that can be crushed using the pressure of the thumb and forefinger thereby releasing fibres (AHERA 1986). Friability of building materials were assessed for a subset of samples in the laboratory to determine their ability to be crushed by hand pressure. Findings revealed that manufactured building materials such as corrugated asbestos cement sheet panels and water pipes were not typically friable. However, locally made building materials, including concrete blocks, bricks and concrete slabs may be friable if they have been significantly degraded and are exposed to the elements. Damaged material has a greater likelihood of releasing fibres, especially if a protective coating has been breached (or was never established).

Dustiness testing (such as EU Method 15051) measures the propensity of a material to release airborne dust. Burdett (2008) have documented that fragments of asbestos containing cement building materials (such as asbestos cement pipe fragments) when placed in a rotating drum dustiness test will readily release fibres to the atmosphere. Studies of asbestos cement waste in soil demonstrate that material thickness, mean fibre length, asbestos content of the material and fibre pullout rates are variables in determining the resulting fibre concentrations in soil with ten to twenty percent of the exposed fibres lost to the surrounding soil (van Alphen 2008). Conversely, materials that are well maintained, coated with paint or another form of sealant are less of a hazard as the fibres are retained within the material rather than being released to the environment (HEI 1991). In fact, asbestos concentrations within buildings with asbestos containing building materials that are well maintained and in good condition have been found to be no greater than the outside ambient levels (HEI 1991) including informal housing constructed in South Africa. Despite these air quality findings, soil samples collected along the base of the walls (underneath ACM roofs) were found to contain significant fibre levels when analysed by the methods prescribed by Davies et al (1996) (Dr. J. Philips, 2008 pers. Comm. 16 October). Studies by the South African National Centre of Occupational Health (NCOH) of respondents from Soweto reported that 52% of 1 488 six-month-old infants, were living in asbestos-roofed houses with more than 63% older than 20 years, and that ceilings were absent in 62% of such houses. Leaking roofs, water damage and flaking interior paint in 17%, 13% and 14% of asbestos-roofed houses, respectively, indicated considerable infrastructural decay. In 6% of houses, household members reported cutting or sawing the asbestos roofs during the prior six-month period. Only 10% of respondents were aware of the health effects of asbestos exposure (Mathee et al. 2000).

Step 3: Determine the fibre release potential through the land use and accessibility

Accessibility to occupants is a significant factor in that material that is accessible can be damaged, and frequent usage may lead to abrasion, friction, vibration or other disturbances which can increase the capacity to release asbestos fibres into the environment. ACBM that is disturbed through construction, demolition or routine maintenance activities such as drilling, cutting or sawing may lead to significant short-term exposures. Studies in the 1970s showed that cutting asbestos cement pipes with an abrasive saw caused exposures measured at 26-109 f/ml and cutting asbestos cement sheets with a high speed power saw produced airborne fibre levels as high as 20 f/ml (Noble et al., 1977 [as quoted by

Castleman, 1996]). Disturbing these materials greatly increases the risk of exposure. For the purposes of this model fibre release potential is determined by a combination of three factors. Material that is identified as NAD by laboratory analysis is not considered in this assessment, though it could contain asbestos at very low levels (below trace amounts). Material that is contaminated at trace amounts (less than one percent) is considered to have a Low fibre release potential regardless of its location within a building. Material that is contaminated above trace levels and within a typically inaccessible portion of a building (an area that is not subject to continual occupation or normal activity such as a contaminated floor slab below a layer of vinyl sheet flooring or a roofing material such as asbestos-cement corrugated roof sheets is considered to be a Moderate risk for fibre release. All other materials, regardless of their level of contamination (such as block or plaster walls) are considered to be a High risk since they are easily accessible and may be disturbed or subject to constant wear and abrasion.

Step 4: Determine the potential exposure period (Constant, Regular or Intermittent)

Asbestos is most dangerous when fibres are inhaled into the lungs. Fibres can become airborne when they are agitated through erosion from wind or mechanical forces (i.e., continuous scraping of a door over an asbestos containing cement floor), abrasions (such as cutting into an asbestos cement sheet with a hand saw), or agitation (such as walking or running through soil contaminated with asbestos fibres). Previous studies have documented that very low levels (trace amounts) of asbestos fibres in soil can become airborne at concentrations above occupational exposure limits due to agitation (such as sweeping). Most studies of airborne asbestos exposures related to activities have been concerned with occupational settings (defining exposure based on job category). Very little exposure data exists for routine household activities such as cleaning or routine repair to asbestos surfaces. The US EPA developed a conceptual exposure model for Libby, Montana and identified the primary source of asbestos in the ambient air is released from contaminated soil in and around the community, contaminated indoor air results from activities that occur on a regular basis in the main living space of the home. Asbestos may be transported from contaminated outdoor soil into the home via shoes, clothing, pets, etc. Once in indoor dust, asbestos may become suspended in the air as a result of normal human indoor activities. Breathing air inside a vehicle that has been contaminated with asbestos through open windows is also considered an exposure scenario in this context. Breathing outdoor air near a soil disturbance, dust or mining waste contaminated with asbestos releases fibres into the air with the highest levels occurring in the immediate proximity to the disturbance. Activities may include a wide range of normal behaviours such as children playing in the soil, adults performing garden chores, sports activities, maintenance and installation work, etc. (USEPA 2003b).

According to Peipins et al. (2003) persons may be exposed to more than one of these pathways and for this reason exposure and risk evaluation should consider the cumulative exposure potential to the community. Exposure potential is actually a function of the material's accessibility and the typical activities associated with the land use. For instance, asbestos cement roofs are typically not accessible to individuals (except during maintenance work, etc) regardless of the land use. However, exterior asbestos containing wall and roofing materials such as block or sheet cement products are accessible and where they occur in a residence for instance, can lead to regular to constant fibre release due to disturbances (physical contact and abrasion).

The potential for exposure to the environmental asbestos contamination identified in this research is primarily defined by the land use and associated activities that may occur in and around the ACBM and its accessibility. It is well documented that disturbing asbestos containing materials can lead to increased exposures (USEPA 1988, Sawyer 1991). Conversely ACM that is not likely to be disturbed holds less danger of causing human exposure. The land use of the survey sites was thus used as a surrogate for the risk of exposure based on the types of activities anticipated to occur with the land use category. Of the thirteen land uses identified ten were determined to represent the potential for "active" outdoor land uses wherein soil disturbing activities could be expected (including walking, running, gardening, excavating, etc), or active indoor land uses such as working, playing, or cleaning. Indoor passive activities are also common. However, only one exposure scenario is applied to each land use, and therefore those land uses that could be used actively and passively used were assigned to the "active" category. Within these types of active uses, actual exposure levels could vary greatly depending upon a host of variables. Only three land use categories were determined to represent "passive" type land use activities (non-active open space/open veld, rehabilitated and unrehabilitated mine dumps and cemeteries). Not all of the active land use categories represent sites that are likely to be occupied continuously or for significant periods of time. Therefore, active land use types were further classified based on their anticipated level of exposure as follows:

Intermittent applies to land uses that are only visited on a periodic or infrequent basis such as, cemeteries, police stations, and open space sites. Buildings where the primary occupancy is by employees are not included as these are regulated under the occupational exposure limits of the Occupational Health and Safety Act of 1993. In addition most ACBM is subject to periodic maintenance or disturbance activities and will likely be disturbed at least infrequently. This can be from tradesmen or from owners/occupants who are not adequately informed of the presence of ACBM. Therefore the minimum level of exposure potential is identified as intermittent.

Regular exposure is likely to occur from sites that are frequented on a daily or routine basis by the same individuals. Schools, churches, businesses, playgrounds, roads and sports fields are examples of this type of potential for regular public exposure. Exposure to employees should be considered regular for certain land uses such as offices or commercial businesses. However, worker exposure is regulated under the OHSA Asbestos Regulations (2001) and is therefore not addressed in this research.

Constant exposure applies to residential settings where the potential for exposure to asbestos is almost continual, in particular for home-based workers, the elderly and young children.

Accessibility is defined as the opportunity for people to come into contact with the ACBM. Most ACBM is considered accessible with the exception of roofs and ceilings or subsurface layers (such as fill under an intact foundation slab.

Step 5: Assign an initial risk classification

Based on an evaluation of the abovementioned criteria each site assessed as part of the community survey was initially classified according to a Risk Assessment Category of *Average*, *Significant* or *Severe*, based on an evaluation of building materials only (Table 7.1). Within the context of this research, these terms are defined as follows:

Average Risk – means a site that contains ACBM that is generally in good to fair condition, has low to moderate fibre release potential and intermittent to regular exposure periods. ACBM that is in poor condition must have low fibre release potential and only intermittent exposure periods to be considered Low risk. Average risk sites are also those with No Asbestos Detected (NAD). As previously stated, NAD does not necessarily mean that the site is free of any asbestos contamination as additional sampling could identify contamination to be present. These sites are not considered a high priority for remediation but could be reclassified under re-inspection.

Significant Risk – means a site that contains ACBM in good condition but with moderate fibre release potential and constant exposures or high fibre release potential and regular to constant exposures. ACBM in fair condition with constant exposure periods and low fibre release potential or regular to constant exposure potential and moderate to high fibre release potential also results in a Significant risk. Poor condition ACBM that has low fibre release potential and regular to constant exposure, or moderate exposure potential and intermittent to regular exposures is also a Significant risk. Significant risk sites may be considered a high priority for remediation if in close proximity to other Significant or Severe risk sites.

Severe Risk – means a site that has ACBM in fair condition but high fibre release potential and constant exposures, or poor condition with moderate fibre release potential and constant exposure or high fibre release potential and regular to constant exposures. These sites should be considered a high priority for remediation efforts.

Step 6: Determine if asbestos contaminated soil is present

Soil that is contaminated with asbestos fibres and asbestiform fragments can generate copious amounts of dust when disturbed and these dust clouds can contain significant amounts of asbestos fibres within the biologically active size class. Furthermore, in addition to the direct exposure potential for those individuals and bystanders who may be directly exposed the fibres can also be transported inside dwellings and other buildings. Detailed testing in Libby identified that 70 percent of the indoor dust found within dwellings is derived from outdoor soil. The presence of asbestos in outdoor soil was correlated with an increased detection frequency and average concentrations of asbestos in indoor dust. Lastly, the greater the number of vectors and the poorer condition of the adjacent garden area, the greater the anticipated transfer of outdoor soil into interior dust (USEPA 2007). Thus contaminated soils, at any quantity identified using the screening level assessment conducted as part of this investigation was determined to be a contributory factor to risk.

If ACBM is present and the soil is NAD (based on site specific sampling), then the risk determination should proceed to Step 6. If ACBM is present and the soil is known to be contaminated with asbestos at any level of concentration (not NAD), or, if soil was not sampled (it is then presumed to be asbestos contaminated), then the initial risk classification should be increased by one level. For instance, a site with ACBM that is in poor condition, with low fibre release potential and regular exposure and asbestos contaminated soil should be reclassified from Moderate to High.

Step 7: Determine if children are likely to be present

A key point concerning environmental exposures to ambient fibre concentrations is the age of first exposure and the duration of exposure. It has been previously discussed that the age of first exposure is an important factor for determining risk of contracting an asbestos related disease. It has also been well established (in South Africa and elsewhere), that environmental exposures do lead to asbestos related cancer, including mesothelioma and that a number of reported cases appear in people who were mostly likely exposed as children (due to the latency period) and for relatively short periods of time. All ARD are thought to be dose-dependent and contain a fairly long latency periods. The longer the period of exposure occurs the greater the cumulative dose and that equates to a higher likelihood of contracting an ARD. Thus the age of exposure is an important risk factor for ARD (Berman and Crump 1999; ATSDR 2001). According to census data there are approximately 48 000 children under the age of five within the Wards within a five kilometre radius of mine and dump sites and 192 000 children under the age of 20.

As previously stated, there is no "safe" level of exposure to asbestos. No lower threshold of safe exposure has been determined for either serpentine or amphibole fibres. However, risk is related to the age of first exposure, duration of exposure, and concentration of fibres in the air of a respirable size range. The age of first exposure is important as it relates to the latency period of asbestos related diseases. The earlier someone is exposed to fibres, the more opportunity exists for the onset of disease. With latency periods of at least 20 years, occupational exposures result in disease burdens that typically appear after the age of 40. In contrast, environmental exposures may manifest themselves in disease much earlier pointing to childhood exposures. Children are thought to be especially vulnerable to asbestos exposure though there is little scientific evidence to substantiate these concerns due to a lack of studies being conducted (ATSDR 2003). First, small children's lungs are still developing and may be more susceptible to disease. Second, children play on and near the ground surface and are naturally curious about their environment. This brings them into closer contact with contaminated media such as soil and building material. Third, playing induces open-mouth breathing which allows fibres of a greater size range to be inhaled into the more distal portions of the lung's interior. Therefore, allowable environmental exposure levels must take into consideration the protection of children as the most vulnerable cohort.

Once the initial risk classification and the assessment of soil contamination have been completed, then the final risk criteria must be determined. For reasons stated above children are thought to be the most vulnerable segment of the population with respect to potential for exposure and risk of disease. Land uses or locations that have the potential for exposure to children should be considered a higher priority for remediation. For the purposes of this risk characterization, residences (regardless of whether children were present during the community survey) were considered a high potential for childhood exposure. Schools, including pre-schools and daycares and playgrounds or sports fields were also considered a high risk. Contaminated roads within residential areas, due to the documented high dust levels generated by vehicles, are also considered high risk. For these land uses, the risk category should be increased by one level. For instance, a residence that would otherwise qualify as a Significant risk level should be re-classified to a Severe risk since it has the potential for childhood exposure. This factor should be applied regardless of the age of current occupants due to the transitory nature of populations. Once these adjustments are complete, then the Final Risk Classification for the site is recorded. Unless there are any extraneous issues not identified in the process above that may alter the final risk assessment determination, the final classification should be used to assign risk levels and for prioritization for remediation planning.

7.2.4. Risk-based environmental asbestos model for soils

Numerous land uses within the Study Area (such as roads, playgrounds, dump sites and open veld) were assessed as part of this research using the RBEAM. For sites that do not contain ACBM, or where the building material was not sampled, and the soil was assessed, the RBEAM described in Figure 7.2 was used. This five step decision-tree process is similar to that described above with the same definitions utilized.

Table 7.2: Risk-based Environmental Asbestos Exposure Model for soils

LAB	EXPOSURE	INITIAL RISK	EXPOSURE	FINAL RISK

ANALYSIS FOR SOIL STEP 1	POTENTIAL STEP 2	CLASSIFICATION STEP 3	POTENTIAL FOR CHILDREN STEP 4	CLASSIFICATION STEP 5
NAD	NA	Low	No	Low
			Yes	Moderate
Asbestos Detected	Intermittent	Low	No	Low
			Yes	Moderate
	Regular	Moderate	No	Moderate
			Yes	High
	Constant	High	NA	High

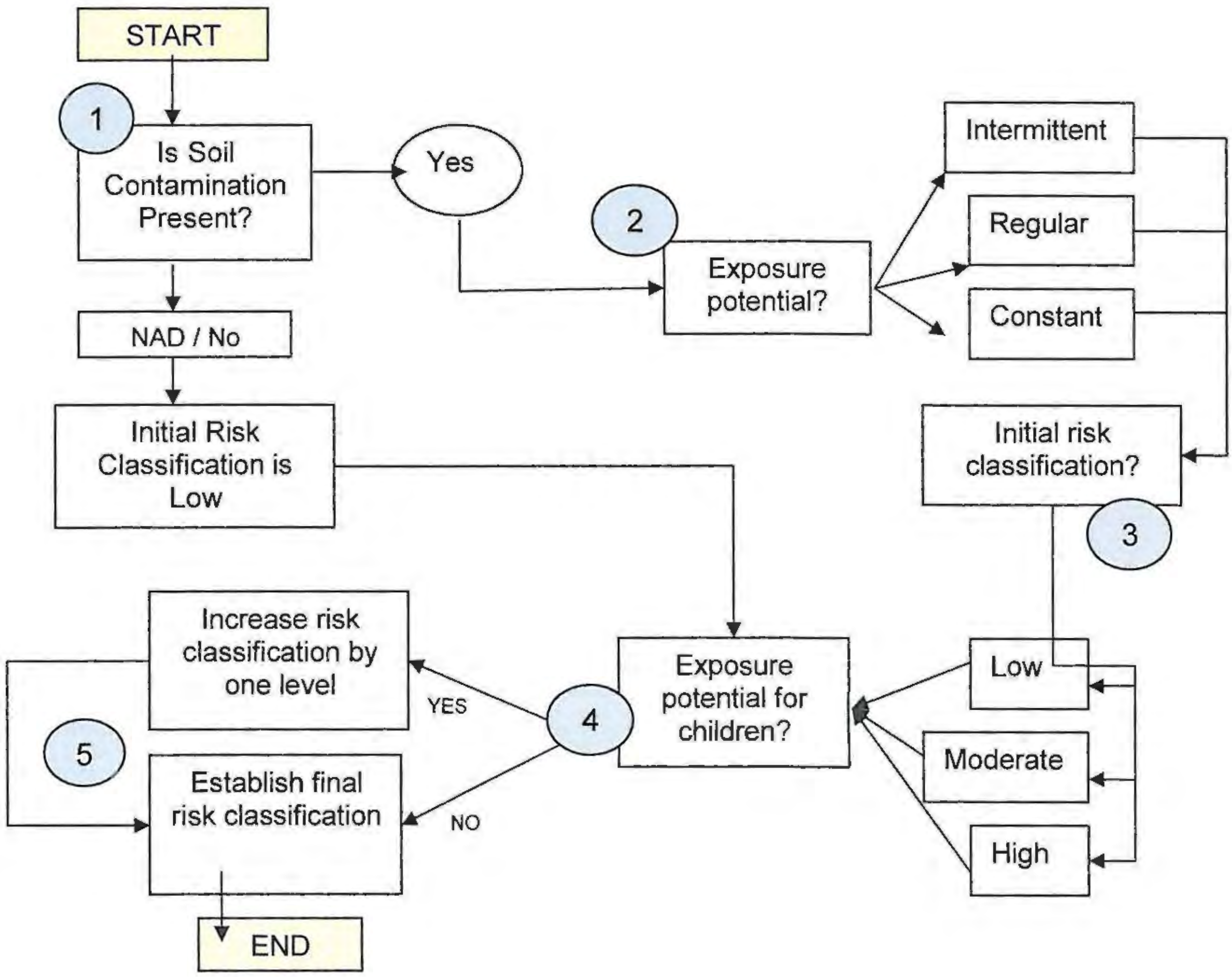


Figure 7.2: Risk-based environmental asbestos model for soil (RBEAM$_{soil}$)

7.3. Results

7.3.1. Results of laboratory analysis

A total of 3 335 samples were collected within the Study Area as part of this research and all were then assessed using the methodology described in Section 4.2.2. Of the total number of samples collected by the initial screening-level assessment, 1 360 were of soil and 489 building materials. The initial screening-level assessment revealed that soils were contaminated at a rate of 38% for all samples and building materials were contaminated at a rate of 65%. The detailed survey of Ga-Mopedi added an additional 1,335 soil samples and 151 building material samples. Rates for the detailed survey were generally lower with soil contaminated at 14.8% and building materials at 6%. The reasons for this difference are discussed in section 7.4.

7.3.2. Results of building material assessment

Friable block was only reported in 28% of the samples (n=71). However of those identified to be in poor condition (71.4%, n = 35), only 33% were determined to be both in poor condition and friable thus there was no statistical correlation between the two parameters. The cement mixture of local soil and asbestos is resistant to crushing by hand pressure and is therefore not "friable" using the regulatory definition of the word however it may still easily release fibres from abrasion or friction as the building material is rarely adequately covered or sealed nor is it fire-hardened to increase its durability and resistance to the elements. Many of the samples analysed contained copious amounts of dust within the sample container from the abrasion of sample transport yet the residual bulk material did not meet the classic definition of friability. Based on physical examination of the materials it was clear that the locally constructed blocks are capable of releasing dust upon mechanical abrasion and from physical deterioration. When assessing the combination of asbestos contaminated blocks in poor condition and/or those that were friable are applied against the total potential buildings with asbestos containing block this results in a significant number of poor condition and/or friable building materials for the Study Area. The condition of the building material is perhaps a better arbiter of its ability to release fibres.

This survey has determined the majority of building materials identified by this research as containing asbestos were constructed of local materials. Of the ten categories of building materials assessed as part of this research, "block" had the highest percentage of containing asbestos (88% n = 145). Photos 7.1 and 7.2 are examples of local blocks being prepared with soils obtained from on-site. Earth building is the most common method of making cheap accommodation since soil is readily available almost anywhere on the planet. According to Houben and Guild (1994 as quoted by Adam and Agib 2001) 30% of the world's population and fifty percent of the population (mostly rural) within developing countries live in a home of unbaked earth. The use of on site soils in the formation of building materials, primarily block, plaster and foundation materials has been documented by Mabiletja (1991), Felix (1997), Randeree (1998), Moodley et al. (2001), McCulloch (2002) and confirmed by this research.

7.3.3. Results of fibre release potential

Fibre release potential was assessed for all building materials surveyed within the Study Area. Of the 489 building material samples assessed 318 were determined to be asbestos contaminated. Table 7.4 provides the results per building material type. Of the 318 positive samples roofs were determined to be the only material with a low fibre release potential. The roofs were commercially manufactured asbestos-cement corrugated panels and are generally more resistant to deterioration (though not immune) than locally constructed building materials. Furthermore, they are generally not as accessible to the inhabitants.

Table 7.3: Building material results for the Study Area by type

BUILDING MATERIAL TYPE	TOTAL NUMBER OF SAMPLES	ACBM & (PERCENT OF TOTAL)
Roofs	27	22 (82%)
Ceiling	8	5 (63%)
Plaster	33	13 (39%)
Bricks	78	45 (58%)
Block	145	127 (88%)
Concrete	4	3 (75%)
Mortar	31	21 (68%)
Foundation slab material	145	72 (50%)
Floor	9	7 (78%)
Non-descript building material	9	3 (33%)
Totals	489	318 (65%)

A total 26 building materials were contaminated at trace levels and therefore determined to have a Low fibre release potential. Roof samples, even though contaminated at rates of greater than 50 percent asbestos (typically a mixture of crocidolite and chrysotile) are assessed as moderate risk since they were commercially produced and generally out of reach of occupants (with the exception of occasional maintenance or repair work). The remaining building materials (274 samples) were identified as High risk for fibre release potential due to their greater than trace levels and accessibility to inhabitants. Figure 7.3 shows the quantities of asbestos contamination for all building material samples expressed as an estimated percent of the building material by volume per the laboratory results.

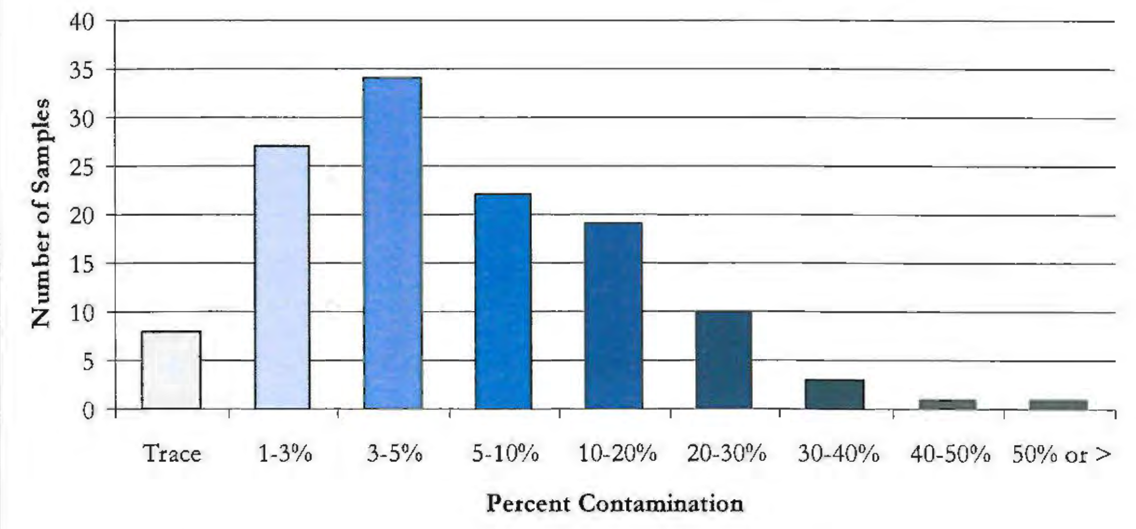


Figure 7.3: Levels of contamination for all ACBM

7.3.4. Exposure period

ACBM results were assessed based on the land use as a proxy for the estimated exposure period. Eight different land uses were represented by the contaminated building material samples and classified accordingly (Table 7.5).

Table 7.4: Land use classifications and exposure periods for ACBM

LAND USE	EXPOSURE PERIOD	NUMBER OF SAMPLES
Open Space	Intermittent	2
Graveyard	Intermittent	2
Churches	Regular	10
Hospital/Clinic	Regular	4
Private Business	Regular	2
Public Buildings	Regular	11
Schools	Regular	30
Residences	Constant	258

7.3.5. The presence of contaminated soil

The risk assessment model increases the initial risk classification by one category for sites where asbestos contaminated soil is present. For those sites were building materials were not sampled or did not exist due to the land use, the decision tree model for soil (Figure 7.2) was used. Each site was included in the screening level assessment was assessed based on this methodology. Contaminated soil was present at 278 sites (63.5 percent) of the 438 total sites assessed by this method.

7.3.6. The potential for children to be present

The risk assessment model increases the classification of each site if there is a potential for childhood exposure. This increase in the initial risk classification was completed for each site based on the associated land use and increased by one on 426 sites (97.3%) of the 438 assessed. A minimal number of land uses such as magistrate's offices, police stations and graveyards were determined to not have the potential for children to be present (under normal conditions).

7.3.7. Validation with Ga-Mopedi detailed survey results

The results of this model indicate a significant trend for a Significant to Severe risk result (combined 98 percent). In order to determine if this methodology is reflective of the actual conditions and can be extrapolated to other non-surveyed locations, additional research was completed. A primary determinant in this risk assessment model is the existence of soil and its likelihood of being disturbance thus leading to human exposures. The methodology stipulates that if asbestos contaminated soil is present at any level (per the preferred microscopic analysis methodology) and with intermittent exposures and the potential for childhood exposures, the risk ranking will be Significant. At regular exposures the risk will also be Significant but with childhood exposures possible, it was regarded as Severe. Any constant exposure will be a Severe risk regardless of whether children may be exposed or not. Thus the existence of contaminated soil and the exposure potential for children are the primary determinants in the risk ranking paradigm developed by this research. The land use classification is used as a surrogate for the determination if children are potentially exposed.

In order to test the validity of this methodology, the Ga-Mopedi community was surveyed in detail with a particular focus on the existence of asbestos contaminated soils in and amongst residential stands but also including adjacent land uses that may have constant exposures or childhood exposure potential. A total of 321 homes were surveyed (n=436) with 1 335 soil samples collected. Table 7.6 compares the results of the screening level assessment and the detailed survey. The detailed survey concluded that where soil contamination is present within a residential land use, the risk ranking will always be high and results indicate that all of the homes found to contain asbestos contamination will be ranked as high risk and that in most communities surveyed, residential uses are the predominant land use. Residential stands represent the largest land use by area coverage and number within the surveyed communities. Within Ga-Mopedi the residential uses represent 96.5 percent of the identified stands.

This research when compared to other surveys using similar methodologies confirmed a consistency in the percentage of residential contamination. The presence of asbestos contaminated soil was found to be a major determinant in that only 3.3% of sites surveyed contained building material contamination but no soil contamination whereas 24.9% of the sites were positive for soil contamination. When combined the overall rate of contamination was 26% for Ga-Mopedi. Building materials were positive for asbestos in 6% of the samples obtained (n=151) but in 24.9% of the soils (n=1 335) thus you are four times more likely to find soil contamination than building materials and over seven times more likely to find soil contamination when both materials are surveyed at the same site. However, in order to avoid false negatives, the risk assessment must also include building materials and their condition, in addition to the presence of soil in order to accurately estimate risk and not undercount the total extent of contamination. For the purpose of remediation planning building material contamination should also be assessed.

Table 7.5: Comparison of results of the screening level survey to the detailed Ga-Mopedi residential land use surveys

RESULTS FOR GA-MOPEDI HOMES	SCREENING-LEVEL SURVEY	DETAILED SURVEY
Total Number of Homes Reported In the Community	333	436
Total Number of Homes Surveyed/(%) for Soil Contamination	16 (5.7%)	321 (74%)
Number of Soil Samples Collected /Asbestos Detected	77/56 (1 untested = 73%)	335/197 (14.8%)
Number of Homes Testing Positive for Soil Contamination/Surveyed	16/17 (94%)	80/321 (24.9%)

7.4. Discussion

These results confirm that the RBEAM is a useful tool for evaluating the severity of contamination when applied to the specific results of the screening level assessment. This research has demonstrated that the model developed is easily translated to field inspectors who with minimal training can easily complete the required assessments. It does not predict the percentage of contaminated versus non-contaminated sites within a given community nor was it designed to do so. In the example of Ga-Mopedi the risk ranking of the sites surveyed during the screening level assessment identified 31 out of 33 (94%) as Severe risk. The ranking conducted as a result of the detailed assessment identified that 96.5% of the stands within the community are residential and of those found to be contaminated, all but five contained either soil contamination or soil and building material contamination. Of the five with only building material contamination (soil = NAD), three were ranked as Significant risk and two were ranked as Severe risk bringing the total number of Severe risk sites to 77 out of the total of 84 or 92%. Thus the ranking per the RBEAM was within two percentile of the detailed assessment. It is then reasonable to assume that 92-94 percent of the homes found to be contaminated with asbestos in either soil or building materials will be ranked as a Severe risk. Adding the results of the other seven land uses surveyed within Ga-Mopedi during the detailed assessment does not alter the findings by a significant margin due to their overall low prevalence within the community. Only one of the seven land uses represented by 16 separate sites was found to represent intermittent exposure periods (graveyards) and they were not found to have contaminated soil (three locations, n=15 samples).

Within the Study Area a total of nine communities resulted in 100% of the sites surveyed being ranked as Severe risk. Due to the paucity of sites and/or samples within the four communities, they represent a total of only 11 locations in aggregate (<3% of the total sites sampled). Communities such as Bodulong and Kuruman also contain a relatively high percentage of sites in the High risk category (3 in Bodulong and 7 in Kuruman) but each had relatively low percentages of sites surveyed to the total existing). It is important to note that these results are not the product of a comprehensive survey wherein all potential sites of contamination were investigated. They rather serve to illustrate those communities that were suspected to contain environmental asbestos contamination based on the results of the predictive model described in Chapter 3 were in fact contaminated and at risk for exposures to the population. Table 7.7 provides a listing of the communities surveyed within the Study Area and the results of the application of the risk assessment model.

Table 7.6: Results of application of the RBEAM to the screening-level results

VILLAGE / COMMUNITY	TOTAL ASSESSED	AVERAGE	SIGNIFICANT	SEVERE
Bankhara	5	0	4	1
Bodulong	5	1	1	3
Draghoander	3	0	2	1
Groenwater	1	0	1	0
Jenhaven	2	0	2	0
Kathu	2	0	0	2
Koegas	3	0	0	3
Kuruman	15	2	7	6
Owendale	1	0	1	0
Prieska	21	0	11	10
Wandrag	5	0	0	5
Westerberg	1	0	0	1
Wrenchville	18	1	12	5
Batlharos	49	0	16	33
Galotolo	5	0	0	5
Ga-Mopedi	33	0	2	31
Ga-Motsamai	11	0	5	6
Heuningvlei	87	1	35	50
Gasehubane	6	0	1	5
Maruping	24	0	10	13
Masonkong	12	0	2	10
Ncweng	2	0	1	4
Pietboos	2	0	0	2
Pomfret	5	0	3	2
Gateshikedi	6	0	4	2
Sedibeng	19	0	2	17
Seven Miles	6	0	5	1
Sloja	4	0	1	3
Tshukudung	8	0	4	4

Village / Community	Total assessed	Average	Significant	Severe
Tsineng	5	0	1	4
Seodin	11	0	8	3
Maipeng	14	0	2	12
Magojaneng	18	0	0	18
Mothibistad	9	2	7	0
Magobing	12	0	0	12
Vergenoeg	8	0	3	5
Totals: 36	**439**	**7 (2%)**	**153 (35%)**	**279 (63%)**

This risk ranking also allows for GIS mapping of the results. Figure 7.4 is a map of the output of the risk assessment model for Ga-Mopedi and provides an example of how this model can be used to assess for spatial trends in the location of contamination as well as planning for remediation activities (risk management). When compared to the door to door survey of stands within Ga-Mopedi there is good correlation as to the extent of contamination between the results of the screening level risk assessment and the identification of contaminated stands within the community.

7.5. Conclusions

As a model to estimate the severity of contamination the RBEAM is a useful tool to quickly and efficiently evaluate a site to determine its potential risk to the inhabitants or occupants. It may be used solely or in combination with other models (such as the KAPI for roads) where conditions dictate. It is the first model developed to estimate risk using a combination of laboratory derived analysis of samples (soil and building material), material condition, accessibility and childhood exposure potential (using land use as a surrogate) within South Africa or elsewhere based on a literature review.

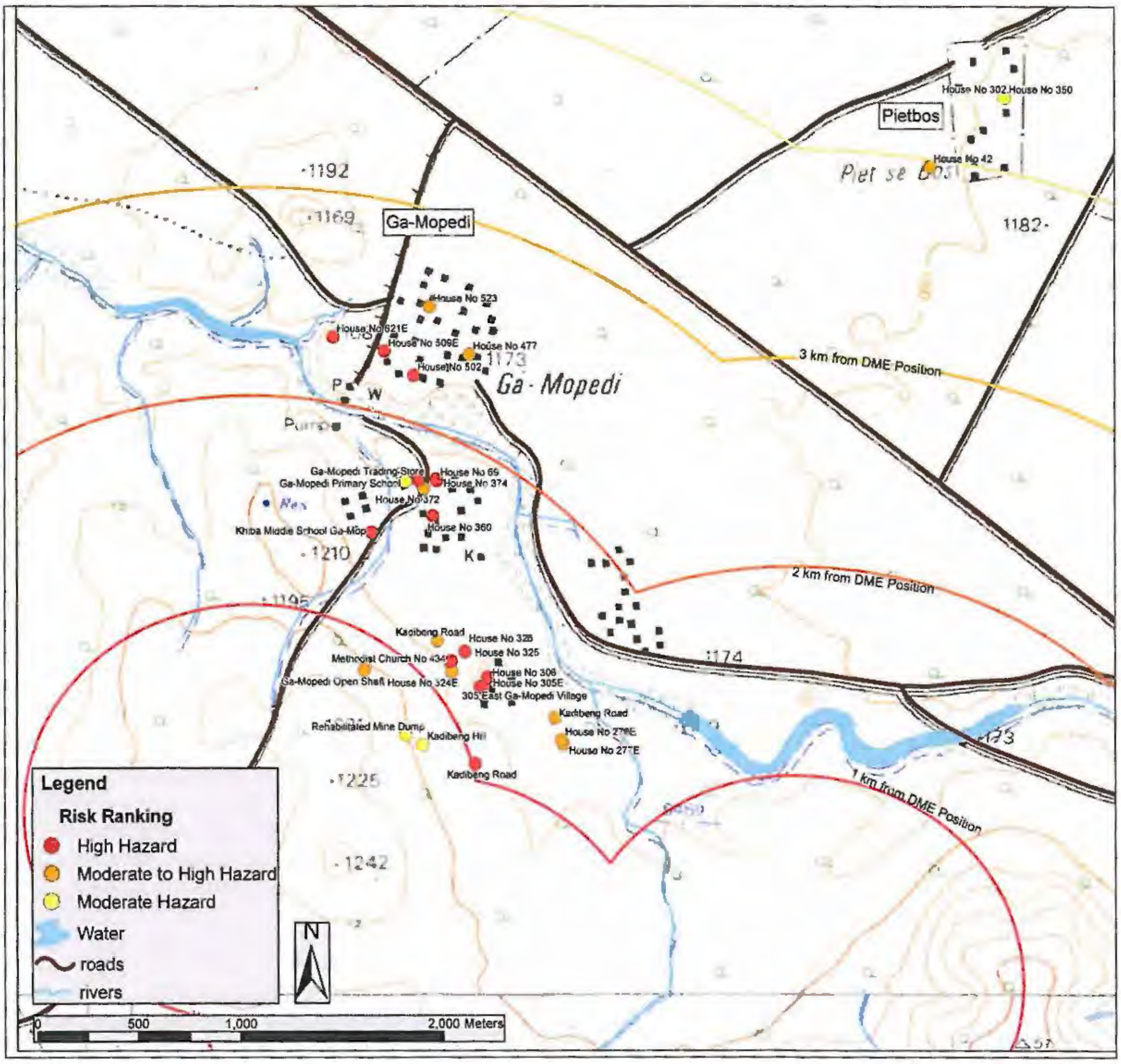


Figure 7.4: Output of risk model for Ga-Mopedi using a modified risk classification of High, Moderate to High, Moderate, Low to Moderate and Low

It has also been developed for applications where there may be a shortage of skilled environmental health professionals or scientists available to conduct more detailed exposure surveys. This model, as developed, has been applied to a total of 49 communities within South Africa to date with the results reported to the national Department of Environmental Affairs (DEA). After initial training by this researcher, much of the model's field data were collected by non-professional representatives of the local communities. With the exception of the laboratory analysis the other steps in the process can be completed rapidly based on the data collected during the field investigation. The laboratory method does not require extensive microscopy training or sophisticated equipment (such as air sampling pumps or electron microscopy). It is designed to assess large geographic areas requiring a semi-quantitative assessment of conditions and resulting risks to the local populations. It represents the first effort to systematically and uniformly assess environmental risk across multiple communities in an attempt to determine the severity of contamination (from a human health risk perspective) using data collected at specific locations. Given its limitations it is a very useful and data-rich analysis of conditions within the Study Area that supports the quantitative model presented in Chapter 6. Additional testing such as activity-based sampling (ABS) should be conducted to validate the assumptions of exposure and quantify their intensities and durations. This model has application for other regions where asbestos was mined or used as waste materials within residential settings. Countries such as China, Russia, India, Pakistan, Brazil, Zimbabwe and others may find its application useful as a rapid screening level approach to determining the severity of environmental contamination from asbestos mine and industrial waste.

CHAPTER 8

8. CONCLUSIONS AND RECOMMENDATIONS FOR FUTURE RESEARCH

I am really happy you are conducting this research. We need to know what is happening to us.[28]

8.1. Introduction

"High levels of environmental asbestos pollution continue to threaten the health and well-being of those who reside in the former asbestos mining areas of South Africa. This risk-based assessment confirmed what has been suspected and anecdotally reported for decades: that, harmful levels of environmental asbestos threaten the lives of current and future generations in the former asbestos mining regions of the Northern Cape and Northwest Province. Much more should be done to determine the scale and severity of this national disaster. The citizens at risk are often disempowered and poverty-stricken. It is common cause that the scale and potential cost of rehabilitation is formidable. Where clean-ups and rehabilitation are not possible, evacuation of affected communities should be considered." (Gibson, per comm. 2009). Asbestos is a worldwide occupational and environmental hazard of catastrophic proportions responsible for over 90 000 deaths per year worldwide (LaDou et al. 2001; ILO 1986). It will likely cause millions more deaths worldwide with many of these in developing countries that lack resources to adequately reduce risks and meet the increased costs of healthcare. The profound tragedy of the asbestos epidemic is that all illnesses and deaths related to asbestos are entirely preventable (LaDou et al. 2001). This research has sought to define the true extent and severity of environmental asbestos contamination within a major portion of the former asbestos mining region of South Africa. This chapter reviews the results of this research starting with the objectives that were defined in chapter one. It follows with a summary of the major findings and concludes with suggestions for future research in this field.

The first objective of this research was to develop and employ a methodology for quickly and efficiently assessing the environmental contamination in the

[28] Quote by a resident of G-Mopedi during interviews conducted within Ga-Mopedi 08 April 2009.

communities surrounding the former asbestos mining regions. This methodology was then employed to identify and document the extent, scope and severity of environmental asbestos contamination in the regions surrounding the former asbestos mines within the Northern Cape and North West provinces, specifically those communities within ten kilometres of former mine sites.

A second objective was to develop a cumulative exposure assessment for those populations within the Study Area environmentally exposed to asbestos contamination as defined by the first objective. Specific exposure indices developed at other locations were used in conjunction with primary data to predict population exposures within the Study Area. The third objective of this research was to develop a risk assessment approach for determining those locations and activities that may lead to human exposure to asbestos fibres and apply the model to the affected communities. The goal was to provide a method for prioritizing those sites and communities for remediation.

This research included a comprehensive survey within areas suspected of containing environmental contamination as a result of former asbestos mining. The survey results have been input into the structured risk assessment model developed to identify those communities and locations most at risk for asbestos exposure. The systematic, targeted sampling strategy documented the location, type and condition of asbestos contamination within the Study Area. A risk-based prioritisation model for decision-making was developed and applied to the results. The objectives of this research that were achieved include the following:

- Develop and apply a contextually specific methodology to assess the areal extent of environmental asbestos contamination within the Study Area (former asbestos mining region of the Northern Cape and North West provinces of South Africa) starting a coarse level of desk-top assessment and leading to a detailed investigation of a representative community. The results were used to map the extent of environmental asbestos contamination.

- Develop and apply a risk-based assessment methodology that is contextually appropriate to determine the relative risk to the environmentally exposed portion of the Study Area population

- Apply airborne concentrations derived from case studies and field data to the environmentally exposed population in order to estimate the potential disease burden based on the extent of contamination and resulting risk-based assessment methodology

- Validate and calibrate the models based on a detailed investigation of one representative community within the Study Area and then assess the model's results in light of other published data for similar conditions within selected representative case studies.

8.2. Summary

This research was initiated to fill a gap in the current understanding as to the true scope of the environmental contamination of asbestos within South Africa. Prior to the initiation of this research there was a vague understanding of the extent and severity of environmental asbestos contamination within the region. Limited surveys of varying methodologies had been employed in isolated locations but no comprehensive surveys of a large geographic region had been accomplished. Furthermore, it was necessary to develop a methodology that was contextually appropriate in order for it to be applied to the Study Area. The methodology may have applications for other similarly situated countries. Lastly, this research attempted to take the findings to a point of expressing the importance of the results in a format that is relevant to international case studies so that it can be evaluated in comparison with other similar locations such as Wittenoon, Australia and Libby, Montana in the United States. The approach is one that will facilitate the planning for remediation actions designed to reduce the risk to the resident population.

The provinces where asbestos mining previously occurred represent an area larger than many European countries. This poses a significant challenge as traditional asbestos sampling methodologies are aimed at providing results for very specific points on the ground. Thus, it was determined that the geographic scope should be systematically refined to initially assess only those communities considered to be most at-risk for contamination based on their proximity, physical landscape and local knowledge regarding past land use activities and practices. In addition the sampling and laboratory methods must be robust enough to accurately characterise the region given the inherent limitations of resources. The findings of the research are summarized in more detail below.

8.2.1. Initial desk-top assessment

- Reliance upon a strict radius method would have missed a number of very contaminated communities and thus reduced substantially the validity of this research.
- The use of an arbitrary centre point to identify a mine or dump site is not accurate. Mines and dumps, in many cases, cover a large geographical area (several square kilometres). Also, given the history and range of mining techniques, from individual tributors to large commercial shaft mines, a more appropriate approach is to field survey all visible remnants of mining activities and plot them using a polygon to identify the outer boundary. A buffer can then be calculated from the outer limits.
- The DME point files are not always accurate. In some cases there was no evidence a mine ever existed at the locations identified in the database.
- Local knowledge was important in determining the land uses and other activities that influence the spread of contamination. Distances from the source were important considerations, but other factors such as the accessibility of the site and other potentially (closer) sources of building materials were also important considerations. These other factors could only be assessed by interviews with local inhabitants and field inspections by trained inspectors.
- The transport routes for asbestos (either raw ore, hand-cobbed, or processed) are not accurately reflected on topographic maps. This information was more often gathered from local knowledge.

Combining local indigenous knowledge and proper field assessment techniques yielded better results when used in combination with the desk-top level than just the desk-top approach by itself. As an initial screening tool it is useful but only if the radius is extended to encompass a larger number of potentially contaminated communities. The use of a one kilometre circle as a starting point would perhaps be more appropriate with a five kilometre radius extending out beyond that (thus in fact creating a six kilometre radius). With respect to the Study Area this would have picked up an additional number of communities such as Tsnineng which was included based on the local facilitator's knowledge or Mamoratwe and Geelboom which were not. In fact, most communities that did not fall within the five kilometres radius are at a considerable distance from the identified source points with most being closer to ten kilometres. Thus the combination of standardized radius and local knowledge is the most appropriate approach for this level of assessment.

8.2.2. Visual versus laboratory methodologies for asbestos detection

The current assessment method commonly employed in South Africa and elsewhere relies upon an initial visual examination of the environment to identify asbestos contamination. This is due to a historical tendency of environmental contamination to be the result of improperly disposed of industrial or commercial asbestos containing materials. However, within the Study Area, contamination was predominantly within the soils and thus it was determined that the current visual method should be tested against other more refined methodologies with a goal of identifying those with the highest degree of accuracy using the BATNEEC principle. Chapter four demonstrated that visual assessment of asbestos contamination surrounding the former asbestos mining regions of South Africa may be sufficient to detect areas grossly contaminated where soil and building material concentrations are greater than one percent. This is demonstrated by the lack of false positives between the visual and stereomicroscopy analysis. This method is useful as long as the constraints of accuracy are clearly understood by the user. Unfortunately, the vast majority of areas found to be contaminated are represented by levels less than one percent (trace) yet these areas, when disturbed are still capable of inducing airborne concentrations of asbestos that exceed acceptable levels (Davies et al. 1996). Therefore, the absence of visual contamination is not indicative of a complete absence of contamination or of a level that is sufficiently low enough to be protective of human health, especially where it is within close proximity to human occupation and regular use. Additionally, given the resource constraints in South Africa, and likely in many other developing nations, the ability to quickly screen for areas grossly contaminated by asbestos is needed and thus some form of visual assessment is likely to be used as at least a "first pass" at locating areas suspected of environmental contamination. If the contamination is visible to the naked eye than it is present in quantities that should cause concern for public health. Overall, the preferred methodology of stereomicroscopy is valid for the identification of asbestos contamination in soils and building materials when used as a non-quantitative screening method. However, the results should not be used as the sole determinant in defining risk for exposure as there is a potential to miss fibre concentrations at trace levels.

8.2.3. Community screening-level surveys

The results of the initial desk-top level assessment presented in Chapter three were used to identify those communities where more detailed investigations could determine the specific extent and severity of contamination using the preferred sampling and laboratory methodologies described in Chapter four. The geographic scope of this effort, (36 individual communities surveyed and 441 individual sites with 1 843 individual samples analysed), determined that 34 out of the 36 communities surveyed contained some level of environmental contamination. Based on the results of this research the overall rate of contamination was 73 percent for all land uses combined. Since the sample locations were not selected on a random basis, statistical extrapolation was not possible. For this reason, one community (Ga-Mopedi) was selected as being representative of the overall Study Area. A more thorough home to home survey of the community was completed in order to test the veracity of the initial targeted survey results and to provide a higher level of confidence in statistical extrapolation to the remaining communities. A total of 436 homes and 18 other sites were surveyed within Ga-Mopedi (1 625 samples) in order to establish the total extent of contamination within this community. Residences in Ga-Mopedi were contaminated at a rate of 26 percent with two sections of contaminated roads and one school (Khiba Middle) also identified as contaminated.

This research, including the sampling and analysis of 36 communities over two provinces of South Africa represents one of the largest surveys in geographic scope conducted to date for environmental asbestos contamination. Based on the latest census data (South Africa Census 2001) there are approximately 20,933 households within the communities surveyed by this research. Using the average rate of contamination based on the detailed survey of Ga-Mopedi (26.2 percent of all homes) yields a total of 5 484 homes that may be contaminated with asbestos within these communities. This does not include the number of schools, roads, churches, public buildings and other land uses included in this research. At an average occupancy rate of 4.5 persons per household this equates to a resident population of approximately 25 000 people potentially exposed to asbestos in their homes on an on-going basis (*Ibid.* and consistent with the results of the Ga-Mopedi survey). However, with the exception of Ga-Mopedi, the sampling density is characterized as a screening level survey only as the intensity is not sufficient to characterize any one community or site in order to develop site specific remediation plans.

The results indicate that two conditions are evident. One, the survey was effective at targeting those sites suspected of containing asbestos contamination and therefore captured the majority of the extent of contamination. Results of the targeted surveys captured a much greater percentage of individual locations (all land uses) that were in fact contaminated with asbestos versus the comprehensive (door to door) community survey. Thus, the targeted survey, using trained and local facilitators was an accurate method for identifying locations of contamination but was not useful in extrapolating those rates to a larger non-surveyed population. The results cannot be relied upon to represent the total extent of contamination in any one community as they were conducted at a screening level. However, they are effective at defining the approximate limits of contamination in a rapid and cost effective manner and thus are also helpful in prioritizing those communities that represent the most urgent need for follow up investigations and remediation.

8.2.4. Quantitative theoretical exposure assessment

Given the ubiquitous nature of the environmental contamination within many of these communities, it is in fact, the entire community population that is at risk for exposure. The results presented in Chapter five illustrate the geographic extent of environmental asbestos contamination but they do not present the information in terms of its significance to the residents of the region. With respect to the severity of contamination this research developed two methodologies to estimate the risk to the resident population. First, ambient and activity-based air quality sampling was completed during this research and compared to published studies to develop a quantitative exposure model. Different unit risk factors were inserted and the model was then applied to the resident populations of the Study Area (using Ward data) in order to predict the disease burdens within these communities. The predicted rates of mesothelioma (25 per 100 000 population per year) for the Study Area are significantly higher than other reported findings with the exception of Kielkowski et al. (2000). These rates are higher than those reported for Libby, Montana and Wittenoom, Australia two of the more infamous examples of environmental asbestos contamination where billions of Rand have been spent on remediation, research, legal and medical costs.

8.2.5. Qualitative risk assessment

In order to demonstrate a link between the geographic extent of environmental contamination identified in the Study Area and the need for a risk-based prioritization for remediation, this research developed a qualitative risk assessment model and applied it to the results of the targeted surveys. Qualitative criteria were developed and applied to the findings of this research in order to determine if the contamination of soils and building material is likely to generate significant human health risk at the particular locations surveyed as part of the community level assessment. A total of 439 sites were assessed and 35 percent were determined to represent a significant risk and an additional 279 (63 percent) were classified as a severe risk. The model was found to be a useful tool for categorizing the severity of environmental contamination based on the potential risk to the Study Area population. It has been applied to a total of 49 communities within South Africa to date with the results reported to the national Department of Environmental Affairs (DEA). It is designed to assess large geographic areas requiring a semi-quantitative assessment of conditions and resulting risks to the local populations. Furthermore, it represents the first effort to systematically and uniformly assess environmental risk across multiple communities in an attempt to determine the severity of contamination (from a human health risk perspective) using data collected at specific locations. Given its limitations it is a very useful and data-rich analysis of conditions within the Study Area that supports the quantitative model presented in Chapter 6. Countries such as China, Russia, India, Pakistan, Brazil, Zimbabwe and others may find its application useful as a rapid screening level approach to determining the severity of environmental contamination from asbestos mine and industrial waste.

8.3. Suggestions for future research

This research has attempted to quantitatively and qualitatively define the true extent and severity of environmental asbestos contamination within the Study Area. However during the course of its development it has also identified specific constraints to the applied methodologies as well as specific needs for additional research. The following is a summary of the data gaps that are still to be filled related to environmental asbestos exposures within South Africa.

1) The desk-top level preliminary risk screening targeted communities within two to five kilometres of known mine sites. The inclusion of local knowledge expanded this range to closer to ten kilometres with statistical analysis indicating a slope that corresponds to a necessary buffer radius of nine kilometres for communities and a maximum of 12.7 km for individual residences. This research recommends that a comprehensive survey be conducted to include all communities within a ten kilometre radius of known DME sites for all four asbestos mining provinces.
2) The preferred laboratory methodology utilizes a combination of visual and microscopic methods for determining the presence of asbestos fibres. While the preferred methodology is accurate given its technological limitations, more refined analysis with more sophisticated methods (such as scanning electron or transmission electron microscopy) will likely decrease the occurrence of false negatives (reported as NAD) for the presence of asbestos fibres. Alternatives methods such as Davies et al. (1996) have proven accurate as well. Unfortunately, these methods are considerably more intensive in both logistical and financial inputs. Even applying them to only the NAD reported results will require substantially greater investments in both training and laboratory capacity given the scope of the problem. The use of the Davies et al. (1996) method may be a suitable compromise between the use of the preferred method and the more sophisticated and

expensive electron microscopy methods. The Davies et al. (1996) method should be investigated within South Africa to determine its applicability and effectiveness at accomplishing a greater level of method sensitivity without substantially increasing the costs of laboratory analysis.

3) The sample collection and assessment methods have shown to be reliable with sufficient ability to replicate the results. However additional modification to the methodology should be considered as it is applied throughout the Study Area. This research recommends additional activity-based sampling should be completed within the Study Area on a much greater extent than that completed as part of this research. The results of activity-based sampling, combined with the qualitative risk assessment process will yield more data that can be used to refine the risk assessment methodology.
4) The use of unit risk factors specific to the predominant type of contaminant (crocidolite for the Study Area) should be used in lieu of a standardized risk factors fitted to all types of asbestos as are currently used by the US EPA. There is sufficient weight of evidence to justify the use of contaminant specific unit risk factors. This will result in substantially higher predicted rates of lung cancer and mesothelioma for the Study Area and other amphibole producing regions of the county (namely Limpopo) but lower rates for the chrysotile region (Mpumalanga) than would otherwise be predicted using the US EPA standard.
5) Lastly, and most importantly, extrapolated results and theoretical models do not take the place of primary data collected within the Study Area. With respect to the actual prevalence of ARD within the subject communities, this research recommends that health screenings be conducted of all adults to establish the specific rates of ARD including segregation of those that are primarily occupational versus environmentally induced. While computerised tomography (CT) scans are the most accurate, given the lack of access and poor mobility of the rural Study Area population, this research recommends x-ray analysis by trained readers to identify radiographic changes related to environmental exposures. These health screenings should be initiated immediately by the South African Department of Health and the results

should be communicated to the residents and the Department of the Environment (DEA).

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APPENDIX A: SCREENING-LEVEL DATA FORM

COMMUNITY ASBESTOS CONTAMINATION SURVEY
ASBESTOS INTEREST GROUP (AIG)

Name of Inspector: Robert R. Jones ____________

Temp.:
Wind:

Name of Assistant: Stephen Kotoloane ____________

Sample Code	

Date of Inspection: ____________

District Municipality: ____________ Local Municipality: ____________

Town/Village: ____________ Farm Name: ____________

Ownership: Private: Yes/No Tribal Authority: Yes/No State: Yes/No

Name of Owner: ____________ No. of Inhabitants: ____________

Street Address of Property: ____________

Land Use: Residence __ Church __ School __ Hospital/Clinic __ Open Space __

Public Bldg __ Private Business __ Dump Site __ Cemetery __ Road __ Other __

Site Coordinates: S: ____________ E: ____________
(Draw a sketch on back of sheet of where you take the samples)

SAMPLE NO.	SOIL	COVER (Y/N)	ACCESSIBLE (Y/N)	EXPOSURE (INTERMITTENT – REGULAR – CONSTANT)	VISIBLE FIBRES (Y/N)	CONCEN-TRATION

SAMPLE NO.	BUILDING MATERIAL (ROOF– FOUND.- BLOCK- PLASTER)	CONDITION (GOOD – FAIR – POOR)	ACCESSIBLE (Y/N)	EXPOSURE (INTERMITTENT – REGULAR – CONSTANT)	VISIBLE FIBRES (y/n)	CONCEN-TRATION

APPENDIX B: SCREENING-LEVEL DATABASE

Sample I.D.	Village	Land Use	Location	Descrip/Media	Date	Vis.	Cond.	Friable	Lab Results	Lab	Const.
BBCS-1	Bankhara	School	Bankhara-Bodulong Comb School	Soil	13.04.05	no			NAD	RU	1998
BBCS-2	Bankhara	School	Bankhara-Bodulong Comb School	Soil	13.04.05	no			NAD	RU	1998
BBCS-3	Bankhara	School	Bankhara-Bodulong Comb School	Soil	13.04.05	no			NAD	RU	1998
BBCS-4	Bankhara	School	Bankhara-Bodulong Comb School	Soil	13.04.05	no			NAD	RU	1998
BBCS-5	Bankhara	School	Bankhara-Bodulong Comb School	Soil	13.04.05	no			NAD	RU	1998
BBCS-6	Bankhara	School	Bankhara-Bodulong Comb School	Soil	13.04.05	no			NAD	RU	1998
BBCS-7	Bankhara	School	Bankhara-Bodulong Comb School	Soil	13.04.05	no			NAD	RU	1998
BBCS-8	Bankhara	School	Bankhara-Bodulong Comb School	Building material	13.04.05	yes	Fair		5-10% chry	RU	1998
BBCS-9	Bankhara	School	Bankhara-Bodulong Comb School	Building material	13.04.05	yes			NAD	RU	1998
BBCS-10	Bankhara	School	Bankhara-Bodulong Comb School	Foundation slab material	13.04.05	no			NAD	RU	1998
BBCS-11	Bankhara	School	Bankhara-Bodulong Comb School	Soil	13.04.05	no			NAD	RU	1998
BBCS-12	Bankhara	School	Bankhara-Bodulong Comb School	Soil	13.04.05	no			NAD	RU	1998
BCPS892-1	Bankhara	School	Bodulong Community Pre-School	Soil	13.04.05				NAD	RU	2000
BCPS892-2	Bankhara	School	Bodulong Community Pre-School	Soil	13.04.05				NAD	RU	2000
BCPS892-3	Bankhara	School	Bodulong Community Pre-School	Bricks	13.04.05				NAD	RU	2000
MR888-1	Bankhara	Residence	House No E888	Soil	13.04.05				NAD	RU	2000
MR888-2	Bankhara	Residence	House No E888	Soil	13.04.05				NAD	RU	2000
MR888-3	Bankhara	Residence	House No E888	Soil	13.04.05				NAD	RU	2000
MR888-4	Bankhara	Residence	House No E888	Soil	13.04.05				NAD	RU	2000
MP-1	Bankhara	Public Buildings	Multi-Purpose Centre No 10	Soil	13.04.05				NAD	RU	1998
MP-2	Bankhara	Public Buildings	Multi-Purpose Centre No 10	Soil	13.04.05				NAD	RU	1998
MP-3	Bankhara	Public Buildings	Multi-Purpose Centre No 10	Soil	13.04.05				NAD	RU	1998
MP-4	Bankhara	Public Buildings	Multi-Purpose Centre No 10	Foundation slab material	13.04.05				NAD	RU	1998
MP-5	Bankhara	Public Buildings	Multi-Purpose Centre No 10	Soil	13.04.05				NAD	RU	1998
ME-1	Bankhara	School	Masekhane Educare	Soil	13.04.05				NAD	RU	1998
ME-2	Bankhara	School	Masekhane Educare	Soil	13.04.05				NAD	RU	1998
ME-3	Bankhara	School	Masekhane Educare	Soil	13.04.05				NAD	RU	1998
ME-4	Bankhara	School	Masekhane Educare	Soil	13.04.05				NAD	RU	1998
ME-5	Bankhara	School	Masekhane Educare	Building material	13.04.05				NAD	RU	1998
BCS-1	Bodulong	Private business	Boemedi Cash Store	Bricks	14.04.05	no			NAD	RU	1992
BCS-2	Bodulong	Private business	Boemedi Cash Store	Soil	14.04.05	no			NAD	RU	1992
BCS-3	Bodulong	Private business	Boemedi Cash Store	Soil	14.04.05	no			Trace	RU	1992
BCS-4	Bodulong	Private business	Boemedi Cash Store	Soil	14.04.05	no			NAD	RU	1992

OF-1	Bodulong	Open space	Bodulong/Bankhara Mtns	Soil	14.04.05			NAD	RU	
OF-2	Bodulong	Open space	Bodulong/Bankhara Mtns	Soil	14.04.05			NAD	RU	
OF-3	Bodulong	Open space	Bodulong/Bankhara Mtns	Soil	14.04.05			NAD	RU	
OF-4	Bodulong	Open space	Bodulong/Bankhara Mtns	Soil	14.04.05			NAD	RU	
JB101-1	Bodulong	Residence	House No 101	Plaster	14.04.05			NAD	RU	1978
JB101-2	Bodulong	Residence	House No 101	Soil	14.04.05			NAD	RU	1978
JB101-3	Bodulong	Residence	House No 101	Soil	14.04.05			NAD	RU	1978
JB101-4	Bodulong	Residence	House No 101	Soil	14.04.05			NAD	RU	1978
EN606-1	Bodulong	Private business	Bodulong General Dealer No 606	Soil	14.04.05			NAD	RU	1997
EN606-2	Bodulong	Private business	Bodulong General Dealer No 606	Soil	14.04.05			Trace	RU	1997
EN606-3	Bodulong	Private business	Bodulong General Dealer No 606	Soil	14.04.05			Trace	RU	1997
EN606-4	Bodulong	Private business	Bodulong General Dealer No 606	Bricks	14.04.05			NAD	RU	1997
RPS - 1	Bodulong	School	Recweletse Pre School	Soil	14.04.05			Trace	RU	2001
RPS - 2	Bodulong	School	Recweletse Pre School	Soil	14.04.05			NAD	RU	2001
RPS - 3	Bodulong	School	Recweletse Pre School	Soil	14.04.05			NAD	RU	2001
RPS - 4	Bodulong	School	Recweletse Pre School	Soil	14.04.05			NAD	RU	2001
RJDG-1	Draghoander	Residence	House at rail station	Soil	23.07.05	no		NAD	RU	
RJDG-2	Draghoander	Rail station	Near water tank	Soil	23.07.05	no		Trace crocid	RU	
RJDG-3	Draghoander	Rail station	Behind old hotel	Soil	23.07.05	yes		90-100% crocid	RU	
RJGR-1	Groenwater	Road	Near Chief's house	Soil	07.22.05	no		NAD	RU	
RJJH-1	Jenhaven	Road	Village road	Soil	22.07.05	no		NAD	RU	
RJJH-2	Jenhaven	School	Khosis School	Soil	22.07.05	no		NAD	RU	
RJJH-3	Jenhaven	School	Khosis School	Mortar	22.07.05	no		NAD	RU	
RJJH-4	Jenhaven	School	Khosis School	Ceiling tile	22.07.05	no		NAD	RU	
RJJH-5	Jenhaven	School	Khosis School	Floor tile	22.07.05	no		NAD	RU	
KATU-1	Katu	Residence		Soil	22.07.05	yes		10-20% crocid	RU	
KATU-2	Katu	Residence		Soil	22.07.05	yes		90-100% crocid	RU	
RJKB1	Kougas	Road	Edge of Road	Soil	23.07.05			Trace	RU	
RJKB2	Kougas	Road	Road seams	Road joint filler	23.07.05	yes	no	5-10% crocid	RU	
RJKB3	Kougas	Residence	Dump sites on farm	Soil/Building material in dumps	23.07.05	yes	yes	10-30% crocid	RU	
KOURD2	Kougas	Road	Road from Kougas to Kameelboom	Soil	23.07.05			Trace crocid	RU	
MM1	Kuruman	Church	Moffat Mission	Soil		no	yes	NAD	RU	
KPS-1	Kuruman	School	Kuruman Primary School	Soil	22.04.05	no		NAD	RU	1998
KPS-2	Kuruman	School	Kuruman Primary School	Soil	22.04.05	no		NAD	RU	1998
KPS-3	Kuruman	School	Kuruman Primary School	Foundation slab material	22.04.05	no		NAD	RU	1998
KPS-4	Kuruman	School	Kuruman Primary School	Soil	22.04.05	no		NAD	RU	1998

KPS-5	Kuruman	School	Kuruman Primary School	Soil	22.04.05	no	NAD	RU	1998
KPS-6	Kuruman	School	Kuruman Primary School	Soil	22.04.05	no	Trace	RU	1998
CN-1	Kuruman	Residence	Bree	Soil	17.05.05	no	NAD	RU	
CN-2	Kuruman	Residence	Bree	Soil	17.05.05	no	NAD	RU	
CN-3	Kuruman	Residence	Bree	Soil	17.05.05	no	NAD	RU	
KHA-1	Kuruman	Public Buildings	Home Affairs	Soil	17.05.05	no	NAD	RU	2002
KHA-2	Kuruman	Public Buildings	Home Affairs	Soil	17.05.05	no	NAD	RU	2002
KHA-3	Kuruman	Public Buildings	Home Affairs	Soil	17.05.05	no	NAD	RU	2002
KC-1	Kuruman	Hospital/Clinic	Kuruman Clinic	Soil	06.05.05	no	NAD	RU	1983
KC-2	Kuruman	Hospital/Clinic	Kuruman Clinic	Soil	06.05.05	no	NAD	RU	1983
KC-3	Kuruman	Hospital/Clinic	Kuruman Clinic	Soil	06.05.05	no	NAD	RU	1983
KC-4	Kuruman	Hospital/Clinic	Kuruman Clinic	Stone	06.05.05	yes	NAD	RU	1983
KC-5	Kuruman	Hospital/Clinic	Kuruman Clinic	Soil	06.05.05	no	NAD	RU	1983
KC-6	Kuruman	Hospital/Clinic	Hospital/Clinic	Soil	06.05.05	no	NAD	RU	
KC-7	Kuruman	Hospital/Clinic	Hospital/Clinic	Soil	06.05.05	no	NAD	RU	
KC-8	Kuruman	Hospital/Clinic	Hospital/Clinic	Soil	06.05.05	no	NAD	RU	
KFE-1	Kuruman	Road	Kuruman-Vryburg Road	Soil	06.05.05		NAD	RU	1971
KFE-2	Kuruman	Road	Kuruman-Vryburg Road	Soil	06.05.05		NAD	RU	1971
KFE-3	Kuruman	Road	Kuruman-Vryburg Road	Soil	06.05.05		NAD	RU	1971
KFE-4	Kuruman	Road	Kuruman-Vryburg Road	Soil	06.05.05		Trace	RU	1971
KFE-5	Kuruman	Road	Kuruman-Vryburg Road	Soil	06.05.05		NAD	RU	1971
KFE-6	Kuruman	Road	Kuruman-Vryburg Road	Soil	06.05.05		NAD	RU	1971
KFE-7	Kuruman	Road	Kuruman-Vryburg Road	Soil	06.05.05		NAD	RU	1971
KFE-8	Kuruman	Road	Kuruman-Vryburg Road	Soil	06.05.05		NAD	RU	1971
KCH-1	Kuruman	Hospital/Clinic	Kuruman Community Hospital	Soil	06.05.05		NAD	RU	1983
KCH-2	Kuruman	Hospital/Clinic	Kuruman Community Hospital	Soil	06.05.05		NAD	RU	1983
KCH-3	Kuruman	Hospital/Clinic	Kuruman Community Hospital	Soil	06.05.05		NAD	RU	1983
KCH-4	Kuruman	Hospital/Clinic	Kuruman Community Hospital	Soil	06.05.05		NAD	RU	1983
KCH-5	Kuruman	Hospital/Clinic	Kuruman Community Hospital	Soil	06.05.05		NAD	RU	1983
KCH-6	Kuruman	Hospital/Clinic	Kuruman Community Hospital	Soil	06.05.05		NAD	RU	1983
KCH-7	Kuruman	Hospital/Clinic	Kuruman Community Hospital	Soil	06.05.05		NAD	RU	1983
KCH-8	Kuruman	Hospital/Clinic	Kuruman Community Hospital	Soil	06.05.05		NAD	RU	1983
KCH-9	Kuruman	Hospital/Clinic	Kuruman Community Hospital	Soil	06.05.05		NAD	RU	1983
KMMT-1	Kuruman	Church	Moffat Mission Trust	Soil	28.05.05		NAD	RU	1829
KMMT-2	Kuruman	Church	Moffat Mission Trust	Soil	28.05.05		NAD	RU	1829
KMMT-3	Kuruman	Church	Moffat Mission Trust	Foundation slab material	28.05.05		NAD	RU	1829
KMMT-4	Kuruman	Church	Moffat Mission Trust	Soil	28.05.05		NAD	RU	1829
KMMT-5	Kuruman	Church	Moffat Mission Trust	Soil	28.05.05		NAD	RU	1829

KMMT-6	Kuruman	Church	Moffat Mission Trust	Soil	28.05.05				NAD	RU	1829
RSCC-1	Kuruman	Private business	Red Sands Country Lodge	Soil	25.04.05				NAD	RU	1996
RSCC-2	Kuruman	Private business	Red Sands Country Lodge	Soil	25.04.05				NAD	RU	1996
RSCC-3	Kuruman	Private business	Red Sands Country Lodge	Soil	25.04.05				NAD	RU	1996
RSCC-4	Kuruman	Private business	Red Sands Country Lodge	Soil	25.04.05				NAD	RU	1996
KDR-1	Kuruman	Road	Kuruman-Danielskuil Road	Soil	28.04.05				3-5% crocid	RU	
KDR-2	Kuruman	Road	Kuruman-Danielskuil Road	Soil	28.04.05				3-5% crocid	RU	
KDR-3	Kuruman	Road	Kuruman-Danielskuil Road	Soil	28.04.05				3-5% crocid	RU	
KDR-4	Kuruman	Road	Kuruman-Danielskuil Road	Soil	28.04.05				3-5% crocid	RU	
WWPS SV-1	Kuruman	School	Willie Wallie Pre-School	Soil	22.04.05				Trace	RU	1898
WWPS SV-2	Kuruman	School	Willie Wallie Pre-School	Foundation slab material	22.04.05				NAD	RU	1898
WWPS SV-3	Kuruman	School	Willie Wallie Pre-School	Soil	22.04.05				NAD	RU	1898
WWPS SV-4	Kuruman	School	Willie Wallie Pre-School	Soil	22.04.05				NAD	RU	1898
ORS-1	Kuruman	Railroad Station	Old railway station	Soil	28.04.05				5-10% crocid	RU	
ORS-2	Kuruman	Railroad Station	Old railway station	Soil	28.04.05				20-30% crocid	RU	
ORS-3	Kuruman	Railroad Station	Old railway station	Soil	28.04.05				Trace	RU	
KTR RP-1	Kuruman	Road	Kuruman-Tsineng Road rest stop	Soil	28.04.05				Trace	RU	
KTR RP-2	Kuruman	Road	Kuruman-Tsineng Road rest stop	Soil	28.04.05				Trace	RU	
OAH-1	Kuruman	Residence	Karee Ave Old Age Home	Soil	28.04.05				NAD	RU	1975
OAH-2	Kuruman	Residence	Karee Ave Old Age Home	Soil	28.04.05				Trace	RU	1975
OAH-3	Kuruman	Residence	Karee Ave Old Age Home	Soil	28.04.05				NAD	RU	1975
OAH-4	Kuruman	Residence	Karee Ave Old Age Home	Soil	28.04.05				NAD	RU	1975
KL-1	Kuruman	Private business	Kofman Lodge	Soil	25.04.05				NAD	RU	1957
KL-2	Kuruman	Private business	Kofman Lodge	Soil	25.04.05				Trace	RU	1957
KL-3	Kuruman	Private business	Kofman Lodge	Soil	25.04.05				Trace	RU	1957
K L - 1	Kuruman	Private business	Kuruman Landros	Soil	17.05.05				NAD	RU	1920
K L - 2	Kuruman	Private business	Kuruman Landros	Soil	17.05.05				NAD	RU	1920
K L - 3	Kuruman	Private business	Kuruman Landros	Soil	17.05.05				NAD	RU	1920
K L - 4	Kuruman	Private business	Kuruman Landros	Soil	17.05.05				NAD	RU	1920
K L - 5	Kuruman	Private business	Kuruman Landros	Soil	17.05.05				NAD	RU	1920
K L - 6	Kuruman	Private business	Kuruman Landros	Soil	17.05.05				NAD	RU	1920
K L - 7	Kuruman	Private business	Kuruman Landros	Soil	17.05.05				NAD	RU	1920
K L - 8	Kuruman	Private business	Kuruman Landros	Soil	17.05.05				NAD	RU	1920
OWENDALE1	Owendale	Residence	Owendale community	Roof	22.07.05		Good	no	Asbestos roofs		
PSKA2	Prieska	Church	Old Church	Soil	22.10.04	no	Poor		NAD		
PSKA3	Prieska	Church	Old Church	Soil	22.10.04	no	Poor		Trace	RU	
OLDNG1	Prieska	Church	New Apostolic Church	Soil	09.11.04	no			Trace	RU	1940s
PSKA4	Prieska	School	Initia Primary School	Soil	22.10.04	no	Poor		Trace	RU	

PSKA5	Prieska	School	Initia Primary School	Mortar	22.10.04	no	Poor		NAD	RU	
PSKA6	Prieska	School	Initia Primary School	Foundation slab material	22.10.04	no	Poor		NAD	RU	
PSKA8	Prieska	School	J. Drywer School	Mortar	22.10.04	no			NAD	RU	
PSKA9	Prieska	School	J. Drywer School	Soil	22.10.04	no	Poor		NAD	RU	
PSKA10	Prieska	School	J. Drywer School	Plaster	22.10.04	no	Poor		2% Crocid&40% Chry	Omni	
PSKA11	Prieska	School	J. Drywer School	Roof	22.10.04	no			20% Crocid&20% Chr	Omni	
ASTR1	Prieska	Road	Asbestos Street	Soil	26.11.04	no			NAD	Omni	1990
RailB1	Prieska	Rail	Rail	Soil	26.11.04	no			NAD	RU	
PSKA-PRI1	Prieska	School	Andries Pretorius School	Soil	30.11.04	no			NAD	RU	
PSKA-PRI2	Prieska	School	Andries Pretorius School	Building material	24.07.05	no			NAD		
RailL1	Prieska	Rail	Rail	Soil	26.11.04	no			NAD	RU	
LSTR1	Prieska	Residence	Mans St 25 (Raunkamp)	Plaster	03.11.04	no			NAD	RU	1950s
LTH1	Prieska	Residence	Mans St 31 (Raunkamp)	Mortar	03.11.04	no			NAD	RU	1950s
JJD1	Prieska	School	JJ Drywer School	Soil	08.11.04	no			Trace	RU	1959
JJD2	Prieska	School	JJ Drywer School	Soil	08.11.04	no			NAD	RU	1959
JJD3	Prieska	School	JJ Drywer School	Soil	08.11.04	no			NAD	RU	1959
KS1	Prieska	Residence	Mans St 18 (Rooiblok)	Mortar	03.11.04	no		yes	3-5% crocid	RU	1950s
WA2	Prieska	Residence	Mans St 10	Mortar	03.11.04	no			1-3% crocid	RU	1950s
LST1	Prieska	Residence	Mans St 19 (Raunkamp)	Mortar	03.11.04	no			NAD	RU	1950s
HSP1	Prieska	School	Van Niekerk St (High School)	Soil	08.11.04	no			NAD	RU	1960
HSP2	Prieska	School	Van Niekerk St (High School)	Soil	08.11.04	no			NAD	RU	1960
HSP3	Prieska	School	Van Niekerk St (High School)	Soil	08.11.04	no			NAD	RU	1960
HSP4	Prieska	School	Van Niekerk St (High School)	Soil	08.11.04	no			Trace	RU	1960
HSP5	Prieska	School	Van Niekerk St (High School)	Soil	08.11.04	no			NAD	RU	1960
HSP6	Prieska	School	Van Niekerk St (High School)	Soil	08.11.04	no			NAD	RU	1960
HSP7	Prieska	School	Van Niekerk St (High School)	Soil	08.11.04	no			NAD	RU	1960
BPHOSP1	Prieska	Hospital/Clinic	Hospital	Soil	30.11.04	no			Trace	RU	
BPHOSP2	Prieska	Hospital/Clinic	Hospital	Soil	30.11.04	no			NAD	RU	
BPHOSP3	Prieska	Hospital/Clinic	Hospital	Soil	30.11.04	no			NAD	RU	
BPHOSP4	Prieska	Hospital/Clinic	Hospital	Soil	30.11.04	no			Trace	RU	
BPHOSP5	Prieska	Hospital/Clinic	Hospital	Plaster	24.07.05	no			NAD	RU	
BPHOSP6	Prieska	Hospital/Clinic	Hospital	Mortar	24.07.05	no			NAD	RU	
BPHOSP7	Prieska	Hospital/Clinic	Hospital	Bricks	24.07.05	no			NAD	RU	
BPHOSP8	Prieska	Hospital/Clinic	Hospital	Roof	24.07.05	yes			chry		
BPHOSP9	Prieska	Hospital/Clinic	Hospital	Soil	24.07.05	no			NAD	RU	

HHS1	Prieska	School	Heuwelsig High School	Soil	08.11.04	no			NAD	RU	1978
HHS2	Prieska	School	Heuwelsig High School	Soil	08.11.04	no			NAD	RU	1978
HHS3	Prieska	School	Heuwelsig High School	Soil	08.11.04	no			NAD	RU	1978
HHS4	Prieska	School	Heuwelsig High School	Soil	08.11.04	no			Trace	RU	1978
HHS5	Prieska	School	Heuwelsig High School	Ceiling	24.07.05	no			NAD	RU	1978
HHS6	Prieska	School	Heuwelsig High School	Bricks	24.07.05	no			NAD		1978
HHS7	Prieska	School	Heuwelsig High School	Mortar	24.07.05	no			NAD		1978
HHS8	Prieska	School	Heuwelsig High School	Roof	24.07.05	yes	Poor	no	chry		1978
RDW1	Prieska	School	Burger St (RD Williams School)	Soil	08.11.04	no			NAD	RU	1984
RDW2	Prieska	School	Burger St (RD Williams School)	Soil	08.11.04	no			NAD	RU	1984
RDW3	Prieska	School	Burger St (RD Williams School)	Soil	08.11.04	no			NAD	RU	1984
RDW4	Prieska	School	Burger St (RD Williams School)	Soil	08.11.04	no			NAD	RU	1984
RDW5	Prieska	School	Burger St (RD Williams School)	Soil	08.11.04	no			NAD	RU	1984
PSKA1	Prieska	Rehabilitated Dump	Prieska Dump Site Foot Path	Soil	22.10.04	yes	Poor		Trace		
PSKA12	Prieska	Rehabilitated Dump	Rehab site outside of Prieska	Soil	22.10.04	yes	Poor		Trace	RU	
ASTR2	Prieska	Road	Asbestos Street	Soil	26.11.04	yes			Trace	RU	
WA1	Prieska	Residence	Mans St 10 (Rooiblok)	Plaster	03.11.04	yes		yes	1-3% crocid	RU	1950s
SST1	Prieska	Residence	Mans St 28 (Rooiblok)	Mortar	03.11.04	yes			1-3% crocid	RU	1950s
PSKA7	Prieska	School	Initia Primary School	Air Sample	22.10.04				NAD	NMMU	
Location	Prieska	Rehabilitated Dump	Start of dump sites		22.10.04				No Sample		
Location	Prieska	Rehabilitated Dump	Road crossing of channel	Soil	22.10.04				No Sample		
EXT13-1	Prieska	Road Extension	Old road to Upington	Soil	24.07.05				NAD	RU	
A1	Wandrag	Mine Site	Wandrag Mine Site	Raw fibres	16.10.03	yes	Poor	yes	100% crocid	RU	
A2	Wandrag	Mine Site	Wandrag Mine Site	Raw fibres	16.10.03	yes	Poor	yes	100% crocid	RU	
A3	Wandrag	Mine Site	Wandrag Mine Site	Banded Ironstone	16.10.03	yes in rock seam	Poor	no	crocid	MVA	
RJWB-1	Westerberg	Residence	Old Golf Club	Building material	23.07.05	yes			asbestos pipe debris		1998
WJR43-1	Wrenchville	Residence	Buttekari Street 43	Soil	16.05.05	no			Trace	RU	1964
WJR43-2	Wrenchville	Residence	Buttekari Street 43	Soil	16.05.05	no			NAD	RU	1964
WJR43-3	Wrenchville	Residence	Buttekari Street 43	Soil	16.05.05	no			Trace	RU	1964
WJR43-4	Wrenchville	Residence	Buttekari Street 43	Soil	16.05.05	no			Trace	RU	1964
WJR43-5	Wrenchville	Residence	Buttekari Street 43	Plaster	16.05.05	yes			1-3% crocid	RU	1964
WJR43-6	Wrenchville	Residence	Buttekari Street 43	Block	16.05.05	yes			1-3% crocid	RU	1964
WRW29-1	Wrenchville	Residence	Buttekari Street 29	Soil	16.05.05	no			NAD	RU	1960
WRW29-2	Wrenchville	Residence	Buttekari Street 29	Soil	16.05.05	no			NAD	RU	1960

WRW29-3	Wrenchville	Residence	Buttekari Street 29	Soil	16.05.05	no	NAD	RU	1960
WRW29-4	Wrenchville	Residence	Buttekari Street 29	Soil	16.05.05	no	NAD	RU	1960
WRW29-5	Wrenchville	Residence	Buttekari Street 29	Plaster	16.05.05	yes			1960
WMW27-1	Wrenchville	Residence	Buttekari Street 27	Soil	16.05.05		NAD	RU	1960
WMW27-2	Wrenchville	Residence	Buttekari Street 27	Soil	16.05.05		NAD	RU	1960
WMW27-3	Wrenchville	Residence	Buttekari Street 27	Soil	16.05.05		NAD	RU	1960
WMW27-4	Wrenchville	Residence	Buttekari Street 27	Soil	16.05.05		NAD	RU	1960
WMW27-5	Wrenchville	Residence	Buttekari Street 27	Plaster	16.05.05		NAD	RU	1960
WGSG-1	Wrenchville	Open space	Wrenchville golf sport ground	Soil	13.05.05		NAD	RU	1984
WGSG-2	Wrenchville	Open space	Wrenchville golf sport ground	Soil	13.05.05		NAD	RU	1984
WGSG-3	Wrenchville	Open space	Wrenchville golf sport ground	Soil	13.05.05		NAD	RU	1984
WSG-1	Wrenchville	Open space	Sports grounds	Soil	13.05.05	no	NAD	RU	1984
WSG-2	Wrenchville	Open space	Sports grounds	Soil	13.05.05	no	NAD	RU	1984
WSG-3	Wrenchville	Open space	Sports grounds	Soil	13.05.05	no	NAD	RU	1984
WSG-4	Wrenchville	Open space	Sports grounds	Soil	13.05.05	no	NAD	RU	1984
WSG-5	Wrenchville	Open space	Sports grounds	Soil	13.05.05	no	NAD	RU	1984
WSG-6	Wrenchville	Open space	Sports grounds	Soil	13.05.05	no	NAD	RU	1984
WSG-7	Wrenchville	Open space	Sports grounds	Soil	13.05.05	no	NAD	RU	1984
WSG-8	Wrenchville	Open space	Sports grounds	Soil	13.05.05	no	NAD	RU	1984
WSG-9	Wrenchville	Open space	Sports grounds	Ceiling	13.05.05	yes	pending	RU	1984
WCH-1	Wrenchville	Public Buildings	Community Hall	Soil	13.05.05	no	NAD	RU	
WCH-2	Wrenchville	Public Buildings	Community Hall	Soi	13.05.05	no	NAD	RU	
WCH-3	Wrenchville	Public Buildings	Community Hall	Block	13.05.05	no	NAD	RU	
WEC-1	Wrenchville	Public Buildings	Entertainment Centre	Soil	12.05.05	no	NAD	RU	1984
WEC-2	Wrenchville	Public Buildings	Entertainment Centre	Soil	12.05.05	no	NAD	RU	1984
WEC-3	Wrenchville	Public Buildings	Entertainment Centre	Soil	12.05.05	no	NAD	RU	1984
WEC-4	Wrenchville	Public Buildings	Entertainment Centre	Soil	12.05.05	no	NAD	RU	1984
WPS-1	Wrenchville	Public Buildings	Police Station	Soil	12.05.05		NAD	RU	1990
WPS-2	Wrenchville	Public Buildings	Police Station	Soil	12.05.05		NAD	RU	1990
WPS-3	Wrenchville	Public Buildings	Police Station	Soil	12.05.05		NAD	RU	1990
WPS-4	Wrenchville	Public Buildings	Police Station	Soil	12.05.05		NAD	RU	1990
WPS-5	Wrenchville	Public Buildings	Police Station	Soil	12.05.05		NAD	RU	1990
WPS-6	Wrenchville	Public Buildings	Police Station	Soil	12.05.05		NAD	RU	1990
WEF-1	Wrenchville	Residence	House No E54 Fishfinger	Soil	25.05.05		NAD	RU	1978
WEF-2	Wrenchville	Residence	House No E54 Fishfinger	Soil	25.05.05		NAD	RU	1978
WEF-3	Wrenchville	Residence	House No E54 Fishfinger	Soil	25.05.05		NAD	RU	1978
WEF-4	Wrenchville	Residence	House No E54 Fishfinger	Soil	25.05.05		NAD	RU	1978
WEF-5	Wrenchville	Residence	House No E54 Fishfinger	Roof	25.05.05		>50% chry	RU	1978

WPS-1	Wrenchville	School	Primary School	Soil	24.05.05			NAD	RU	1988
WPS-2	Wrenchville	School	Primary School	Soil	24.05.05			NAD	RU	1988
WPS-3	Wrenchville	School	Primary School	Soil	24.05.05			NAD	RU	1988
WPS-4	Wrenchville	School	Primary School	Soil	24.05.05			NAD	RU	1988
WPS-5	Wrenchville	School	Primary School	Soil	24.05.05			NAD	RU	1988
WPS-6	Wrenchville	School	Primary School	Soil	24.05.05			NAD	RU	1988
WPS-7	Wrenchville	School	Primary School	Soil	24.05.05			NAD	RU	1988
WPS-8	Wrenchville	School	Primary School	Soil	24.05.05			NAD	RU	1988
WPS-9	Wrenchville	School	Primary School	Soil	24.05.05			NAD	RU	1988
WPS-10	Wrenchville	School	Primary School	Soil	24.05.05			NAD	RU	1988
WPS-11	Wrenchville	School	Primary School	Soil	24.05.05			NAD	RU	1988
WPS-12	Wrenchville	School	Primary School	Soil	24.05.05			NAD	RU	1988
WPS-13	Wrenchville	School	Primary School	Soil	24.05.05			NAD	RU	1988
WPS-14	Wrenchville	School	Primary School	Soil	24.05.05			NAD	RU	1988
KSG-1	Wrenchville	School	Kwikstertjie Pre-School	Soil	24.05.05			NAD	RU	1974
KSG-2	Wrenchville	School	Kwikstertjie Pre-School	Soil	24.05.05			NAD	RU	1974
KSG-3	Wrenchville	School	Kwikstertjie Pre-School	Soil	24.05.05			NAD	RU	1974
KSG-4	Wrenchville	School	Kwikstertjie Pre-School	Soil	24.05.05			NAD	RU	1974
DEO-1	Wrenchville	Public Buildings	Dept of Education Office	Soil	24.05.05			NAD	RU	1974
DEO-2	Wrenchville	Public Buildings	Dept of Education Office	Soil	24.05.05			NAD	RU	1974
DEO-3	Wrenchville	Public Buildings	Dept of Education Office	Soil	24.05.05			NAD	RU	1974
DEO-4	Wrenchville	Public Buildings	Dept of Education Office	Soil	24.05.05			NAD	RU	1974
EM6-1	Wrenchville	Residence	Eikelaan E6	Soil	25.05.05			NAD	RU	1977
EM6-2	Wrenchville	Residence	Eikelaan E6	Soil	25.05.05			NAD	RU	1977
EM6-3	Wrenchville	Residence	Eikelaan E6	Soil	25.05.05			NAD	RU	1977
EM6-4	Wrenchville	Residence	Eikelaan E6	Roof	25.05.05			>50% Crocid & Chrys	RU	1977
NH-1	Wrenchville	Private business	Northstar Hotel	Soil	25.05.05			NAD	RU	1988
NH-2	Wrenchville	Private business	Northstar Hotel	Soil	25.05.05			NAD	RU	1988
NH-3	Wrenchville	Private business	Northstar Hotel	Soil	25.05.05			NAD	RU	1988
NH-4	Wrenchville	Private business	Northstar Hotel	Soil	25.05.05			NAD	RU	1988
AS31-1	Wrenchville	Residence	House No E31 Vlei St.	Brick	20.05.05	Poor	yes	10-20% crocid	RU	1910
AS31-2	Wrenchville	Residence	House No E31 Vlei St.	Soil	20.05.05			NAD	RU	1910
AS31-3	Wrenchville	Residence	House No E31 Vlei St.	Soil	20.05.05			Trace	RU	1910
JK31 -1	Wrenchville	Residence	House No E31 Vlei St.	Brick	20.05.05	Poor		NAD	RU	2004
JK31 -2	Wrenchville	Residence	House No E31 Vlei St.	Soil	20.05.05			Trace	RU	2004
WSSS-1	Wrenchville	School	Wrencville Senior Secondary School	Soil	20.05.05			NAD	RU	1996
WSSS-2	Wrenchville	School	Wrencville Senior Secondary School	Soil	20.05.05			NAD	RU	1996

WSSS-3	Wrenchville	School	Wrencville Senior Secondary School	Soil	20.05.05				NAD	RU	1996
WSSS-4	Wrenchville	School	Wrencville Senior Secondary School	Soil	20.05.05				NAD	RU	1996
WSSS-5	Wrenchville	School	Wrencville Senior Secondary School	Floor	20.05.05		Good		NAD	RU	1996
WSSS-6	Wrenchville	School	Wrencville Senior Secondary School	Soil	20.05.05				NAD	RU	1996
WSSS-7	Wrenchville	School	Wrencville Senior Secondary School	Soil	20.05.05				NAD	RU	1996
WSSS-8	Wrenchville	School	Wrencville Senior Secondary School	Soil	20.05.05				NAD	RU	1996
IS - 1	Wrenchville	Residence	Ishmael Shiraaz	Soil	20.05.05				NAD	RU	1965
IS - 2	Wrenchville	Residence	Ishmael Shiraaz	Soil	20.05.05				NAD	RU	1965
BTS-TO1	Batlharos	Public building	Tribal Office	Soil	09.11.04	no			NAD	RU	
BTS-TO2	Batlharos	Public building	Tribal Office	Soil	09.11.04	no			NAD	RU	
BTS-TO3	Batlharos	Public building	Tribal Office	Soil	09.11.04	no		yes	NAD	Omni	
BTS-TO4	Batlharos	Public building	Tribal Office	Soil	09.11.04	no			NAD	RU	
BTS-GK1	Batlharos	Residence	House No 2335	Soil	11.11.04	no			NAD	RU	1990
BTS-GK2	Batlharos	Residence	House No 2335	Foundation slab material	11.11.04	no			NAD	RU	1990
BTS-GK3	Batlharos	Residence	House No 2335	Soil	11.11.04	no			NAD	RU	1990
BTS-GK4	Batlharos	Residence	House No 2335	Soil	11.11.04	no			NAD	RU	1990
BTS-OD2	Batlharos	Residence	House No 2299	Soil	10.11.04	no			Trace	RU	1981
BTS-BD1	Batlharos	Residence	Hostel	Soil	17.11.04	no			NAD	RU	
BTS-BD2	Batlharos	Residence	Hostel	Soil	17.11.04	no			NAD	RU	
BTS-BD4	Batlharos	Residence	Hostel	Soil	17.11.04	no			NAD	RU	
BTS-BD5	Batlharos	Residence	Hostel	Bricks	17.11.04	no			NAD	RU	
BTS-LH1	Batlharos	School	Lesedi High School	Soil	17.11.04	no			NAD	RU	1970
BTS-LH2	Batlharos	School	Lesedi High School	Soil	17.11.04	no			NAD	RU	1970
BTS-LH3	Batlharos	School	Lesedi High School	Foundation slab material	17.11.04	no			NAD	RU	1970
BTS-LH5	Batlharos	School	Lesedi High School	Soil	17.11.04	no			Trace	RU	1970
BTS-LH6	Batlharos	School	Lesedi High School	Soil	17.11.04	no			Trace	RU	1970
BTS-LH7	Batlharos	School	Lesedi High School	Roof	17.11.04	no			NAD	RU	1970
BTS-LH8	Batlharos	School	Lesedi High School	Soil	17.11.04	no			NAD	Omni	1970
BTS-LH9	Batlharos	School	Lesedi High School	Soil	17.11.04	no			NAD	RU	1970
BTS-LH10	Batlharos	School	Lesedi High School	Soil	17.11.04	no			NAD	RU	1970
BTS-KK1	Batlharos	Residence	House No E2437	Foundation slab material	17.11.04	no			NAD	RU	
BTS-KK2	Batlharos	Residence	House No E2437	Soil	17.11.04	no			NAD	RU	
BTS-KK3	Batlharos	Residence	House No E2437	Soil	17.11.04	no			Trace	RU	
BTS-KK4	Batlharos	Residence	House No E2437	Soil	17.11.04	no			NAD	RU	
BTS-KH4	Batlharos	Residence	House No E2325	Soil	11.11.04	no			NAD	RU	1971
BTS-KH5	Batlharos	Residence	House No E2325	Soil	11.11.04	no			NAD	RU	1971
BTS-CJ3	Batlharos	Residence	House No 2544	Soil	17.11.04	no			Trace	RU	1982
BTS-GK1	Batlharos	Residence	House No E2307	Soil	11.11.04	no			Trace	RU	1977

BTS-GK3	Batlharos	Residence	House No E2307	Block	11.11.04	no		Trace	RU	1977
BTS-GK4	Batlharos	Residence	House No E2307	Soil	11.11.04	no		Trace	RU	1977
BTS-GK5	Batlharos	Residence	House No E2307	Soil	11.11.04	no		NAD	RU	1977
BTS-BT2	Batlharos	Residence	House No E2220	Soil	11.11.04	no		Trace	RU	1984
BTS-BT3	Batlharos	Residence	House No E2220	Soil	11.11.04	no		NAD	RU	1984
BTS-BT4	Batlharos	Residence	House No E2220	Soil	11.11.04	no		NAD	RU	1984
BTS-LK1	Batlharos	Residence	House No 2288	Soil	16.11.04	no		Trace	RU	1990
BTS-LK3	Batlharos	Residence	House No 2288	Soil	16.11.04	no		Trace	RU	1990
BTS-LK4	Batlharos	Residence	House No 2288	Soil	16.11.04	no		NAD	RU	1990
BTS-RK1	Batlharos	Residence	House No 2318	Soil	16.11.04	no		NAD	RU	1978
BTS-RK2	Batlharos	Residence	House No 2318	Soil	16.11.04	no		NAD	RU	1978
BTS-RK3	Batlharos	Residence	House No 2318	Soil	16.11.04	no		NAD	RU	1978
BTS-RK4	Batlharos	Residence	House No 2318	Soil	16.11.04	no		NAD	RU	1978
BTS-RK6	Batlharos	Residence	House No 2318	Foundation slab material	16.11.04	no	Poor	3-5%	RU	1978
BTS-CI1	Batlharos	Residence	House No E2348	Soil	17.11.04	no		NAD	RU	1982
BTS-CI2	Batlharos	Residence	House No E2348	Soil	17.11.04	no		NAD	RU	1982
BTS-CI3	Batlharos	Residence	House No E2348	Foundation slab material	17.11.04	no		NAD	RU	1982
BTS-CI4	Batlharos	Residence	House No E2348	Bricks	17.11.04	no	Good	1-3% crocid	RU	1982
BTS-CI5	Batlharos	Residence	House No E2348	Soil	17.11.04	no		Trace	Omni	1982
BTS-CI7	Batlharos	Residence	House No E2348	Soil	17.11.04	no		NAD	RU	1982
BTS-M4	Batlharos	Residence	House No E2312	Soil	11.11.04	no		Trace	RU	1970
BTS-M5	Batlharos	Residence	House No E2312	Soil	11.11.04	no		NAD	RU	1970
BTS-MS1	Batlharos	Residence	House No 2200	Soil	10.11.04	no		NAD	RU	1981
BTS-MS2	Batlharos	Residence	House No 2200	Block	10.11.04	no	Good	1-3% crocid	Omni	1981
BTS-MS4	Batlharos	Residence	House No 2200	Soil	10.11.04	no		NAD	RU	1981
BTS-RP1	Batlharos	School	Robanyane Primary School	Soil	09.11.04	no		NAD	RU	
BTS-RP2	Batlharos	School	Robanyane Primary School	Soil	09.11.04	no		NAD	RU	
BTS-RP3	Batlharos	School	Robanyane Primary School	Soil	09.11.04	no		NAD	RU	
BTS-BB1	Batlharos	Residence	House No E2105	Soil	09.11.04	no		NAD	RU	1960
BTS-BB2	Batlharos	Residence	House No E2105	Foundation slab material	09.11.04	no		NAD	RU	1960
BTS-BM2	Batlharos	Residence	House No E2211	Soil	09.11.04	no		NAD	RU	1970
BTS-BM3	Batlharos	Residence	House No E2211	Soil	09.11.04	no		NAD	RU	1970
BTS-EC2	Batlharos	Residence	House No 2368	Soil	16.11.04	no		NAD	RU	
BTS-EC3	Batlharos	Residence	House No 2368	Soil	16.11.04	no		NAD	RU	
BTS-EC4	Batlharos	Residence	House No 2368	Foundation slab material	16.11.04	no		NAD	RU	
BTS-KL1	Batlharos	Residence	House No 2390	Soil	16.11.04	no		Trace	RU	1970
BTS-KL4	Batlharos	Residence	House No 2390	Foundation slab material	16.11.04	no		NAD	RU	1970
BTS-EI1	Batlharos	Residence	House No 2327	Soil	16.11.04	no		NAD	RU	1982

BTS-EI2	Batlharos	Residence	House No 2327	Soil	16.11.04	no		NAD	RU	1982
BTS-EI3	Batlharos	Residence	House No 2327	Soil	16.11.04	no		NAD	RU	1982
BT-KL1	Batlharos	Residence	House No 2181	Soil	10.11.04	no		NAD	RU	1984
BT-KL2	Batlharos	Residence	House No 2181	Foundation slab material	10.11.04	no		NAD	RU	1984
BT-KL3	Batlharos	Residence	House No 2181	Soil	10.11.04	no		NAD	RU	1984
BTS-MS2	Batlharos	Residence	House No 2003	Soil	10.11.04	no				1990
BTS-BN1	Batlharos	Residence	House No 2291	Soil	16.11.04	no		Trace	RU	
BTS-BN2	Batlharos	Residence	House No 2291	Soil	16.11.04	no		Trace	RU	
BTS-BN3	Batlharos	Residence	House No 2291	Block	16.11.04	no		NAD	RU	
BTS-GM1	Batlharos	Residence	House No E692	Soil	18.11.04	no		NAD	RU	1987+/-
BTS-GM2	Batlharos	Residence	House No E692	Soil	18.11.04	no		NAD	RU	1987+/-
BTS-GM4	Batlharos	Residence	House No E692	Foundation slab material	18.11.04	no		NAD	RU	1987+/-
BTS-TD1	Batlharos	Residence	House No E416B	Soil	18.11.04	no		Trace	RU	
BTS-TD2	Batlharos	Residence	House No E416B	Soil	18.11.04	no		NAD	RU	
BTS-TD4	Batlharos	Residence	House No E416B	Foundation slab material	18.11.04	no		NAD	RU	
BTS-GM1	Batlharos	Residence	House No 535	Soil	18.11.04	no		Trace	RU	
BTS-GM2	Batlharos	Residence	House No 535	Soil	18.11.04	no		NAD	RU	
BTS-GM3	Batlharos	Residence	House No 535	Soil	18.11.04	no		NAD	RU	
BTS-GM4	Batlharos	Residence	House No 535	Soil	18.11.04	no		NAD	RU	
BTS-TB1	Batlharos	Residence	House No E684	Soil	23.11.04	no		NAD	RU	1978
BTS-TB2	Batlharos	Residence	House No E684	Soil	23.11.04	no		NAD	RU	1978
BTS-TB3	Batlharos	Residence	House No E684	Foundation slab material	23.11.04	no		NAD	RU	1978
BTS-GN1	Batlharos	Residence	House No 519	Soil	18.11.04	no		Trace	RU	
BTS-GN2	Batlharos	Residence	House No 519	Soil	18.11.04	no		NAD	RU	
BTS-GN3	Batlharos	Residence	House No 519	Bricks	18.11.04	no		Trace	RU	
BTS-FB1	Batlharos	Residence	House No E228	Soil	18.11.04	no		Trace	RU	1989
BTS-FB2	Batlharos	Residence	House No E228	Soil	18.11.04	no		Trace	RU	1989
BTS-FB3	Batlharos	Residence	House No E228	Soil	18.11.04	no		Trace	RU	1989
BTS-FB4	Batlharos	Residence	House No E228	Soil	18.11.04	no		Trace	RU	1989
BTS-FB7	Batlharos	Residence	House No E228	Soil	18.11.04	no		NAD	RU	1989
BTS-FB8	Batlharos	Residence	House No E228	Foundation slab material	18.11.04	no		NAD	Omni	1989
BTS-OM1	Batlharos	Residence	House No E691	Soil	18.11.04	no		Trace	RU	
BTS-OM2	Batlharos	Residence	House No E691	Soil	18.11.04	no		Trace	RU	
BTS-OM4	Batlharos	Residence	House No E691	Soil	18.11.04	no		Trace	RU	
BTS-TC1	Batlharos	Hospital/Clinic	Tshwaragano Community Hospital	Soil	25.11.04	no		Trace	RU	
BTS-TC3	Batlharos	Hospital/Clinic	Tshwaragano Community Hospital	Soil	25.11.04	no		NAD	RU	
BTS-TC4	Batlharos	Hospital/Clinic	Tshwaragano Community Hospital	Soil	25.11.04	no		Trace	RU	
BTS-TC5	Batlharos	Hospital/Clinic	Tshwaragano Community Hospital	Soil	25.11.04	no		Trace	Omni	

BTS-TC6	Batlharos	Hospital/Clinic	Tshwaragano Community Hospital	Bricks	25.11.04	no			1-3% crocid	RU	
BTS-KJ1	Batlharos	Residence	House No E822	Soil	24.11.04	no			NAD	RU	1971
BTS-KJ2	Batlharos	Residence	House No E822	Soil	24.11.04	no			NAD	RU	1971
BTS-KJ3	Batlharos	Residence	House No E822	Plaster	24.11.04	no			NAD	RU	1971
BTS-KJ4	Batlharos	Residence	House No E822	Foundation slab material	24.11.04	no			NAD	RU	1971
BTS-KJ5	Batlharos	Residence	House No E822	Soil	24.11.04	no			NAD	RU	1971
BTS-HS5	Batlharos	Residence	House No E698	Soil	23.11.04	no			Trace	RU	1980
BTS-AM1	Batlharos	Residence	House No E676	Soil	23.11.04	no			NAD	RU	1974
BTS-AM2	Batlharos	Residence	House No E676	Soil	23.11.04	no			Trace	RU	1974
BTS-AM3	Batlharos	Residence	House No E676	Foundation slab material	23.11.04	no			NAD	RU	1974
BTS-EA3	Batlharos	Residence	House No E732	Foundation slab material	23.11.04	no			NAD	RU	1981
BTS-EA5	Batlharos	Residence	House No E732	Soil	23.11.04	no			NAD	RU	1981
BTS-JM1	Batlharos	Residence	House No E792	Soil	23.11.04	no			NAD	RU	1964
BTS-JM3	Batlharos	Residence	House No E792	Soil	23.11.04	no			Trace	RU	1964
BTS-JM4	Batlharos	Residence	House No E792	Foundation slab material	23.11.04	no	Good		1-3% crocid	Omni	1964
BTS-JM5	Batlharos	Residence	House No E792	Bricks	23.11.04	no	Good	no	1-3% crocid	RU	1964
BTS-DM2	Batlharos	Residence	House No E709	Soil	23.11.04	no			NAD	RU	1974
BTS-FM1	Batlharos	Private business	Borakanelo Trading Store	Soil	24.11.04	no			NAD	RU	1970
BTS-FM3	Batlharos	Private business	Borakanelo Trading Store	Soil	24.11.04	no			NAD	RU	1970
BTS-FM4	Batlharos	Private business	Borakanelo Trading Store	Bricks	24.11.04	no			NAD	RU	1970
BTS-MN1	Batlharos	Residence	House No E1638	Soil	24.11.04	no			Trace	RU	1974
BTS-MN2	Batlharos	Residence	House No E1638	Soil	24.11.04	no			Trace	RU	1974
BTS-SI1	Batlharos	Residence	House No E1049	Soil	24.11.04	no			NAD	RU	1974
BTS-SI3	Batlharos	Residence	House No E1049	Soil	24.11.04	no			Trace	RU	1974
BTS-LT1	Batlharos	Residence	House No E1142	Soil	24.11.04	no			NAD	RU	1974
BTS-LT2	Batlharos	Residence	House No E1142	Soil	24.11.04	no			NAD	RU	1974
BTS-LT3	Batlharos	Residence	House No E1142	Soil	24.11.04	no			NAD	RU	1974
BTS-LT4	Batlharos	Residence	House No E1142	Bricks	24.11.04	no			NAD	Omni	1974
BTS-BPS2	Batlharos	Police Station/Post Ofc	Batlharos Police Station	Soil	25.11.04	no			Trace	RU	1958
BTS-BPS4	Batlharos	Police Station/Post Ofc	Batlharos Police Station	Soil	25.11.04	no			Trace	RU	1958
BTS-BPS5	Batlharos	Police Station/Post Ofc	Batlharos Police Station	Soil	25.11.04	no			Trace	RU	1958
BTS-BPS6	Batlharos	Police Station/Post Ofc	Batlharos Police Station	Soil	25.11.04	no			Trace	RU	1958
BTS-BPS7	Batlharos	Police Station/Post Ofc	Batlharos Police Station	Mortar	25.11.04	no			NAD	RU	1958
BTS-BPS8	Batlharos	Police Station/Post Ofc	Batlharos Police Station	Foundation slab material	25.11.04	no			NAD	RU	1958

BTS-VS5	Batlharos	Residence	House No E974	Foundation slab material	24.11.04	no			Trace	RU	2000
BTS-M1	Batlharos	Church	Batlharos Takeng Mission	Soil	25.11.04	no					1963
BTS-M3	Batlharos	Church	Batlharos Takeng Mission	Soil	25.11.04	no			Trace	RU	1963
BTS-M4	Batlharos	Church	Batlharos Takeng Mission	Soil	25.11.04	no			Trace	RU	1963
BTS-M5	Batlharos	Church	Batlharos Takeng Mission	Foundation slab material	25.11.04	no			Trace	RU	1963
BTS-IV1	Batlharos	Residence	House No E826	Soil	25.11.04	no			Trace	RU	1969
BTS-IV3	Batlharos	Residence	House No E826	Bricks	25.11.04	no			NAD	RU	1969
BTS-LM3	Batlharos	Residence	House No E1053	Bricks	24.11.04	no			Trace	RU	1980
BTS-LM4	Batlharos	Residence	House No E1053	Foundation slab material	24.11.04	no			Trace	RU	1980
BTS-MM1	Batlharos	School	Makuolokwe Middle School	Soil	25.11.04	no			NAD	RU	1979
BTS-MM2	Batlharos	School	Makuolokwe Middle School	Soil	25.11.04	no			NAD	RU	1979
BTS-MM3	Batlharos	School	Makuolokwe Middle School	Soil	25.11.04	no			NAD	RU	1979
BTS-MM4	Batlharos	School	Makuolokwe Middle School	Soil	25.11.04	no			3-5% crocid	Omni	1979
BTS-MM5	Batlharos	School	Makuolokwe Middle School	Soil	25.11.04	no			NAD	RU	1979
BTS-MM6	Batlharos	School	Makuolokwe Middle School	Soil	25.11.04	no			NAD	RU	1979
BTS-OD1	Batlharos	Residence	House No 2299	Foundation slab material	10.11.04	yes	Good		3-5% crocid	RU	1981
BTS-OD3	Batlharos	Residence	House No 2299	Mortar	10.11.04	yes	Good		3-5% crocid	RU	1981
BTS-BD3	Batlharos	Residence	Hostel	Soil	17.11.04	yes			NAD	RU	
BTS-LH4	Batlharos	School	Lesedi High School	Bricks	17.11.04	yes			1-3% crocid	RU	1970
BTS-KH1	Batlharos	Residence	House No E2325	Bricks	11.11.04	yes			3-5% crocid	RU	1971
BTS-KH2	Batlharos	Residence	House No E2325	Soil	11.11.04	yes			1-3% crocid	RU	1971
BTS-KH3	Batlharos	Residence	House No E2325	Foundation slab material	11.11.04	yes			1-3% crocid	RU	1971
BTS-CJ1	Batlharos	Residence	House No 2544	Mortar	17.11.04	yes			>50% crocid	RU	1982
BTS-CJ2	Batlharos	Residence	House No 2544	Bricks	17.11.04	yes			3-5% crocid	RU	1982
BTS-GK2	Batlharos	Residence	House No E2307	Mortar	11.11.04	yes	Poor		3-5% crocid	RU	1977
BTS-BT1	Batlharos	Residence	House No E2220	Block	11.11.04	yes			Trace	RU	1984
BTS-LK2	Batlharos	Residence	House No 2288	Soil	16.11.04	yes			NAD	RU	1990
BTS-LK5	Batlharos	Residence	House No 2288	Mortar	16.11.04	yes	Fair	yes	3-5% crocid	RU	1990
BTS-RK5	Batlharos	Residence	House No 2318	Block	16.11.04	yes			1-3% crocid	RU	1978
BTS-CI6	Batlharos	Residence	House No E2348	Roof	17.11.04	yes			20% chry	Omni	1982
BTS-M1	Batlharos	Residence	House No E2312	Soil	11.11.04	yes			Trace	RU	1970
BTS-M2	Batlharos	Residence	House No E2312	Mortar	11.11.04	yes			1-3% crocid	RU	1970
BTS-M3	Batlharos	Residence	House No E2312	Foundation slab material	11.11.04	yes			3-5% crocid	RU	1970
BTS-MS3	Batlharos	Residence	House No 2200	Soil	10.11.04	yes			NAD	RU	1981
BTS-BM1	Batlharos	Residence	House No E2211	Block	09.11.04	yes			15% crocid	Omni	1970
BTS-JO1	Batlharos	Residence	House No 1972	Block	09.11.04	yes			40-50% crocid	RU	1994
BTS-JO2	Batlharos	Residence	House No 1972	Soil	09.11.04	yes			Trace	RU	1994
BTS-JO3	Batlharos	Residence	House No 1972	Foundation slab material	09.11.04	yes			40-50% crocid	RU	1994

BTS-EC1	Batlharos	Residence	House No 2368	Soil	16.11.04	yes			Trace	RU	
BTS-KL2	Batlharos	Residence	House No 2390	Soil	16.11.04	yes			Trace	RU	1970
BTS-KL3	Batlharos	Residence	House No 2390	Mortar	16.11.04	yes			5-10% crocid	RU	1970
BTS-KL5	Batlharos	Residence	House No 2390	Soil	16.11.04	yes			1-3% crocid	RU	1970
BTS-EI4	Batlharos	Residence	House No 2327	Mortar	16.11.04	yes			10-20% crocid	RU	1982
BTS-MS1	Batlharos	Residence	House No 2003	Soil	10.11.04	yes			10-20% crocid	RU	1990
BTS-MS3	Batlharos	Residence	House No 2003	Block	10.11.04	yes	Good		3-5% crocid	RU	1990
BTS-MS4	Batlharos	Residence	House No 2003	Soil	10.11.04	yes			Trace	RU	1990
BTS-GM3	Batlharos	Residence	House No E692	Bricks	18.11.04	yes		no	1-3% crocid	RU	1987+/-
BTS-TD3	Batlharos	Residence	House No E416B	Soil	18.11.04	yes			10% crocid	Omni	
BTS-TD5	Batlharos	Residence	House No E416B	Bricks	18.11.04	yes		no	1-3% crocid	RU	
BTS-GM5	Batlharos	Residence	House No 535	Bricks	18.11.04	yes		yes	1-3% crocid	RU	
BTS-TB4	Batlharos	Residence	House No E684	Bricks	23.11.04	yes		yes	10-20% crocid	RU	1978
BTS-FB5	Batlharos	Residence	House No E228	Bricks	18.11.04	yes	Good	no	3-5% crocid	RU	1989
BTS-FB6	Batlharos	Residence	House No E228	Bricks	18.11.04	yes	Good	yes	1-3% crocid	RU	1989
BTS-OM3	Batlharos	Residence	House No E691	Soil	18.11.04	yes			Trace	RU	
BTS-OM5	Batlharos	Residence	House No E691	Bricks	18.11.04	yes			Trace	RU	
BTS-TC2	Batlharos	Hospital/Clinic	Tshwaragano Community Hospital	Soil	25.11.04	yes			1-3% crocid	RU	
BTS-TC7	Batlharos	Hospital/Clinic	Tshwaragano Community Hospital	Bricks	25.11.04	yes		no	10-20% crocid	RU	
BTS-TC8	Batlharos	Hospital/Clinic	Tshwaragano Community Hospital	Bricks	25.11.04	yes		no	1-3% crocid	RU	
BTS-HS1	Batlharos	Residence	House No E698	Soil	23.11.04	yes			Trace	RU	1980
BTS-HS2	Batlharos	Residence	House No E698	Soil	23.11.04	yes			3-5% crocid	RU	1980
BTS-HS3	Batlharos	Residence	House No E698	Bricks	23.11.04	yes			1-3% crocid	RU	1980
BTS-HS4	Batlharos	Residence	House No E698	Foundation slab material	23.11.04	yes			10-20% crocid	RU	1980
BTS-AM4	Batlharos	Residence	House No E676	Bricks	23.11.04	yes	Good	yes	1-3% crocid	RU	1974
BTS-EA1	Batlharos	Residence	House No E732	Soil	23.11.04	yes			Trace	RU	1981
BTS-EA2	Batlharos	Residence	House No E732	Soil	23.11.04	yes			Trace	RU	1981
BTS-EA4	Batlharos	Residence	House No E732	Bricks	23.11.04	yes		yes	1-3% crocid	RU	1981
BTS-JM2	Batlharos	Residence	House No E792	Soil	23.11.04	yes			1-3% crocid	RU	1964
BTS-DM1	Batlharos	Residence	House No E709	Soil	23.11.04	yes			1-5% crocid	Omni	1974
BTS-DM3	Batlharos	Residence	House No E709	Bricks	23.11.04	yes		no	1-3% crocid	RU	1974
BTS-DM4	Batlharos	Residence	House No E709	Foundation slab material	23.11.04	yes		yes	1-3% crocid	RU	1974
BTS-DM5	Batlharos	Residence	House No E709	Soil	23.11.04	yes			Trace	RU	1974
BTS-FM2	Batlharos	Private business	Borakanelo Trading Store	Soil	24.11.04	yes			NAD	RU	1970
BTS-MN3	Batlharos	Residence	House No E1638	Bricks	24.11.04	yes		no	5-10% crocid	RU	1974
BTS-SI2	Batlharos	Residence	House No E1049	Soil	24.11.04	yes			Trace	RU	1974
BTS-SI4	Batlharos	Residence	House No E1049	Foundation slab material	24.11.04	yes		no	5-10% crocid	RU	1974
BTS-SI5	Batlharos	Residence	House No E1049	Bricks	24.11.04	yes		no	1-3% crocid	RU	1974

BTS-BPS1	Batlharos	Police Station/Post Ofc	Batlharos Police Station	Soil	25.11.04	yes		NAD	RU	1958
BTS-BPS3	Batlharos	Police Station/Post Ofc	Batlharos Police Station	Soil	25.11.04	yes		Trace	RU	1958
BTS-VS1	Batlharos	Residence	House No E974	Soil	24.11.04	yes		3-5% crocid	RU	2000
BTS-VS2	Batlharos	Residence	House No E974	Soil	24.11.04	yes		NAD	RU	2000
BTS-VS3	Batlharos	Residence	House No E974	Soil	24.11.04	yes		Trace	RU	2000
BTS-VS4	Batlharos	Residence	House No E974	Bricks	24.11.04	yes		3-5% crocid	RU	2000
BTS-M2	Batlharos	Church	Batlharos Takeng Mission	Soil	25.11.04	yes		Trace	RU	1963
BTS-M6	Batlharos	Church	Batlharos Takeng Mission	Foundation slab material	25.11.04	yes	no	1-3% crocid	RU	1963
BTS-IV2	Batlharos	Residence	House No E826	Soil	25.11.04	yes		Trace	RU	1969
BTS-IV4	Batlharos	Residence	House No E826	Foundation slab material	25.11.04	yes	no	5-10% crocid	RU	1969
BTS-LM1	Batlharos	Residence	House No E1053	Soil	24.11.04	yes		NAD	RU	1980
BTS-LM2	Batlharos	Residence	House No E1053	Soil	24.11.04	yes		Trace	RU	1980
GGL-CG1	Galotolo	Residence	House No 2B	Soil	30.11.04	no		Trace crocid	RU	1974
GGL-CG3	Galotolo	Residence	House No 2B	Soil	30.11.04	no		NAD	RU	1974
GGL-DM2	Galotolo	Residence	House No 80B	Soil	30.11.04	no		Trace	RU	
GGL-DM3	Galotolo	Residence	House No 80B	Soil	30.11.04	no		Trace	RU	
GGL-DM4	Galotolo	Residence	House No 80B	Soil	30.11.04	no		Trace	RU	
GGL-DM6	Galotolo	Residence	House No 80B	Plaster	30.11.04	no		Trace	RU	
GGL-DM7	Galotolo	Residence	House No 80B	Concrete	30.11.04	no	no	1-3% crocid	RU	
GGL-IF1	Galotolo	Residence	House No A61	Soil	30.11.04	no		Trace amosite	RU	1978
GGL-IF2	Galotolo	Residence	House No A61	Soil	30.11.04	no		Trace crocid	RU	1978
GGL-IF3	Galotolo	Residence	House No A61	Soil	30.11.04	no		Trace	RU	1978
GGL-IF4	Galotolo	Residence	House No A61	Soil	30.11.04	no		Trace	RU	1978
GGL-IF5	Galotolo	Residence	House No A61	Plaster	30.11.04	no		NAD	RU	1978
GGL-IF6	Galotolo	Residence	House No A61	Foundation slab material	30.11.04	no		NAD	RU	1978
GGL-IF7	Galotolo	Residence	House No A61	Foundation slab material	30.11.04	no		NAD	RU	1978
GGL-PP1	Galotolo	Residence	House No 67A	Soil	30.11.04	no		NAD	RU	1992
GGL-PP2	Galotolo	Residence	House No 67A	Soil	30.11.04	no		NAD	RU	1992
GGL-PP3	Galotolo	Residence	House No 67A	Soil	30.11.04	no		NAD	RU	1992
GGL-PP4	Galotolo	Residence	House No 67A	Soil	30.11.04	no		NAD	RU	1992
GGL-PP5	Galotolo	Residence	House No 67A	Foundation slab material	30.11.04	no		NAD	RU	1992
GGL-EL1	Galotolo	Residence	House No 42	Soil	30.11.04	no		NAD	RU	1999
GGL-EL2	Galotolo	Residence	House No 42	Soil	30.11.04	no		NAD	RU	1999
GGL-EL3	Galotolo	Residence	House No 42	Soil	30.11.04	no		NAD	RU	1999
GGL-EL4	Galotolo	Residence	House No 42	Soil	30.11.04	no		Trace	RU	1999
GGL-CG2	Galotolo	Residence	House No 2B	Soil	30.11.04	yes		Trace	RU	1974
GGL-CG4	Galotolo	Residence	House No 2B	Soil	30.11.04	yes		Trace	RU	1974

GGL-CG5	Galotolo	Residence	House No 2B	Foundation slab material	30.11.04	yes			1-3% crocid	RU	1974
GGL-CG6	Galotolo	Residence	House No 2B	Block	30.11.04	yes			1-3% crocid	RU	1974
GGL-DM1	Galotolo	Residence	House No 80B	Soil	30.11.04	yes			Trace	RU	
GGL-DM5	Galotolo	Residence	House No 80B	Foundation slab material	30.11.04	yes			3-5% crocid	RU	
GGL-DM8	Galotolo	Residence	House No 80B	Mortar	30.11.04	yes		yes	3-5% crocid	RU	
GGL-DM9	Galotolo	Residence	House No 80B	Block	30.11.04	yes			10-20% crocid	RU	
GGL-IF8	Galotolo	Residence	House No A61	Mortar	30.11.04	yes			10-20% crocid	RU	1978
GGL-IF9	Galotolo	Residence	House No A61	Block	30.11.04	yes			5-10% crocid	RU	1978
GGL-PP6	Galotolo	Residence	House No 67A	Block	30.11.04	yes			3-5% crocid	RU	1992
GGL-EL5	Galotolo	Residence	House No 42	Block	30.11.04	yes		no	3-5% crocid	RU	1999
G1	Ga-Mopedi	Residence	305 East Ga-Mopedi Village	Soil	19.10.04	no	Poor		NAD	RU	
G3	Ga-Mopedi	Residence	305 East Ga-Mopedi Village	Mortar	19.10.04	no	Poor		Amosite	RU	
G4	Ga-Mopedi	Residence	305 East Ga-Mopedi Village	Plaster	19.10.04	no	Poor		NAD	RU	
G7	Ga-Mopedi	School	Khiba Middle School Ga-Mop	Plaster	19.10.04	no	Poor		NAD	RU	
G8	Ga-Mopedi	School	Khiba Middle School Ga-Mop	Soil	19.10.04	no	Poor		crocid	RU	
G9	Ga-Mopedi	School	Khiba Middle School Ga-Mop	Soil	19.10.04	no	Poor		crocid	RU	
GMK325-6	Ga-Mopedi	Residence	House No 325	Foundation slab material	11.11.04	no		yes	5-10% crocid	RU	1977
GMK326-1	Ga-Mopedi	Residence	House No 326	Soil	11.11.04	no			NAD	Omni	1976
GMK326-3	Ga-Mopedi	Residence	House No 326	Soil	11.11.04	no			Trace	Omni	1976
GMK326-4	Ga-Mopedi	Residence	House No 326	Soil	11.11.04	no			Trace	RU	1976
GMK306-4	Ga-Mopedi	Residence	House No 306	Soil	11.11.04	no			Trace	RU	1968
GMK305-1	Ga-Mopedi	Residence	House No 305E	Soil	11.11.04	no			1-3% crocid	RU	1968
GMK305-3	Ga-Mopedi	Residence	House No 305E	Soil	11.11.04	no			Trace	RU	1968
GMK305-4	Ga-Mopedi	Residence	House No 305E	Soil	11.11.04	no			Trace	RU	1968
GMK305-5	Ga-Mopedi	Residence	House No 305E	Plaster	11.11.04	no			NAD	RU	1968
GMK305-6	Ga-Mopedi	Residence	House No 305E	Foundation slab material	11.11.04	no			NAD	RU	1968
GMK305-7	Ga-Mopedi	Residence	House No 305E	Block	11.11.04	no			NAD	Omni	1968
GMKLM-1	Ga-Mopedi	Residence	House No 263	Soil	11.11.04	no			NAD	RU	1985
GMKLM-2	Ga-Mopedi	Residence	House No 263	Soil	11.11.04	no			NAD	RU	1985
GMKLM-3	Ga-Mopedi	Residence	House No 263	Soil	11.11.04	no			NAD	RU	1985
GMKLM-4	Ga-Mopedi	Residence	House No 263	Soil	11.11.04	no			NAD	RU	1985
GSDKM-1	Ga-Mopedi	Residence	House No 210B	Soil	24.11.04	no			Trace	RU	1977
GSDKM-2	Ga-Mopedi	Residence	House No 210B	Soil	24.11.04	no			NAD	RU	1977
GSDKM-3	Ga-Mopedi	Residence	House No 210B	Soil	24.11.04	no			NAD	RU	1977
GMK277-4	Ga-Mopedi	Residence	House No 277E	Soil	11.11.04	no			NAD	RU	1990
GMK277-5	Ga-Mopedi	Residence	House No 277E	Soil	11.11.04	no			NAD	RU	1990
GMK324-2	Ga-Mopedi	Residence	House No 324E	Soil	09.11.04	no			Trace	RU	1981
GMK324-5	Ga-Mopedi	Residence	House No 324E	Bricks	09.11.04	no			NAD	RU	1981

GMS374-8	Ga-Mopedi	Residence	House No 374	Mortar	16.11.04	no			1-3% crocid	RU	1965
GMMC-1	Ga-Mopedi	Church	Methodist Church No 434	Soil	16.11.04	no			Trace	RU	1999
GMMC-2	Ga-Mopedi	Church	Methodist Church No 434	Soil	16.11.04	no			NAD	RU	1999
GMMC-3	Ga-Mopedi	Church	Methodist Church No 434	Soil	16.11.04	no			Trace	Omni	1999
GMMC-4	Ga-Mopedi	Church	Methodist Church No 434	Soil	16.11.04	no			Trace	RU	1999
GMMC-5	Ga-Mopedi	Church	Methodist Church No 434	Mortar	16.11.04	no		yes	Trace	RU	1999
GMS360-2	Ga-Mopedi	Residence	House No 360	Soil	16.11.04	no			NAD	RU	1978
GMS360-3	Ga-Mopedi	Residence	House No 360	Soil	16.11.04	no			NAD	RU	1978
GMS360-4	Ga-Mopedi	Residence	House No 360	Soil	16.11.04	no			Trace	RU	1978
GMKSS-3	Ga-Mopedi	School	Khiba Middle School Ga-Mop	Soil	16.11.04	no			Trace	RU	1971
GMD509-1	Ga-Mopedi	Residence	House No 509E	Soil	17.11.04	no			NAD	RU	1978
GMD509-3	Ga-Mopedi	Residence	House No 509E	Soil	17.11.04	no			Trace	RU	1978
GMD523-1	Ga-Mopedi	Residence	House No 523	Soil	17.11.04	no			NAD	RU	1978
GMD523-2	Ga-Mopedi	Residence	House No 523	Soil	17.11.04	no			NAD	RU	1978
GMD523-3	Ga-Mopedi	Residence	House No 523	Soil	17.11.04	no			NAD	RU	1978
GMD523-4	Ga-Mopedi	Residence	House No 523	Soil	17.11.04	no			Trace	RU	1978
GMD523-6	Ga-Mopedi	Residence	House No 523	Foundation slab material	17.11.04	no			NAD	RU	1978
GMD502-1	Ga-Mopedi	Residence	House No 502	Soil	17.11.04	no			Trace	RU	1983
GMD502-2	Ga-Mopedi	Residence	House No 502	Soil	17.11.04	no			NAD	RU	1983
GMD502-3	Ga-Mopedi	Residence	House No 502	Soil	17.11.04	no			NAD	RU	1983
GMTS-3	Ga-Mopedi	Private business	Ga-Mopedi Trading Store	Soil	17.11.04	no			NAD	RU	
GMTS-5	Ga-Mopedi	Private business	Ga-Mopedi Trading Store	Soil	17.11.04	no			NAD	RU	
GMD477-1	Ga-Mopedi	Residence	House No 477	Soil	17.11.04	no			Trace	RU	1979
GMD477-2	Ga-Mopedi	Residence	House No 477	Soil	17.11.04	no			Trace	RU	1979
GMD477-3	Ga-Mopedi	Residence	House No 477	Soil	17.11.04	no			Trace	RU	1979
GMPS-1	Ga-Mopedi	School	Ga-Mopedi Primary School	Soil	17.11.04	no			NAD	RU	1964
GMPS-2	Ga-Mopedi	School	Ga-Mopedi Primary School	Soil	17.11.04	no			Trace	RU	1964
GMPS-3	Ga-Mopedi	School	Ga-Mopedi Primary School	Soil	17.11.04	no			NAD	RU	1964
GMPS-4	Ga-Mopedi	School	Ga-Mopedi Primary School	Soil	17.11.04	no			NAD	RU	1964
GMPS-5	Ga-Mopedi	School	Ga-Mopedi Primary School	Foundation slab material	17.11.04	no			NAD	RU	1964
GV-4	Ga-Mopedi	Residence	374A Ga-Mopedi Village	Soil	25.03.04	yes	Poor	yes	10-15% crocid	Omni	
GV-5	Ga-Mopedi	Residence	374A Ga-Mopedi Village	Building Block	25.03.04	yes	Poor		3-5% crocid	Omni	
G2	Ga-Mopedi	Residence	305 East Ga-Mopedi Village	Soil	19.10.04	yes	Poor		NAD	RU	
G5	Ga-Mopedi	School	Khiba Middle School Ga-Mop	Foundation slab material	19.10.04	yes	Poor		10-20% crocid	RU	
G6	Ga-Mopedi	School	Khiba Middle School Ga-Mop	Block	19.10.04	yes	Poor		1-5% Crocid	RU	
GMK325-1	Ga-Mopedi	Residence	House No 325	Soil	11.11.04	yes			3-5% crocid	RU	1977
GMK325-2	Ga-Mopedi	Residence	House No 325	Soil	11.11.04	yes			Trace	RU	1977
GMK325-3	Ga-Mopedi	Residence	House No 325	Soil	11.11.04	yes			1-3% crocid	RU	1977

GMK325-4	Ga-Mopedi	Residence	House No 325	Soil	11.11.04	yes	Trace	RU	1977
GMK325-5	Ga-Mopedi	Residence	House No 325	Block	11.11.04	yes	10-20% crocid	RU	1977
GMK326-2	Ga-Mopedi	Residence	House No 326	Soil	11.11.04	yes	1-3% crocid	RU	1976
GMK326-5	Ga-Mopedi	Residence	House No 326	Block	11.11.04	yes	3-5% crocid	RU	1976
GMK306-1	Ga-Mopedi	Residence	House No 306	Soil	11.11.04	yes	Trace	RU	1968
GMK306-2	Ga-Mopedi	Residence	House No 306	Soil	11.11.04	yes	3-5% crocid	RU	1968
GMK306-3	Ga-Mopedi	Residence	House No 306	Soil	11.11.04	yes	Trace	RU	1968
GMK305-2	Ga-Mopedi	Residence	House No 305E	Soil	11.11.04	yes	Trace	RU	1968
GKDR-1	Ga-Mopedi	Road	Kadibeng Road	Soil	11.11.04	yes	1-3% crocid	RU	
GMKCR-1	Ga-Mopedi	Road	Kadibeng Road	Soil	11.11.04	yes	1-3% crocid	RU	
GMKR-1	Ga-Mopedi	Road	Kadibeng Road	Soil	11.11.04	yes	>5% crocid	RU	
GMK276-1	Ga-Mopedi	Residence	House No 276E	Soil	11.11.04	yes	Trace	RU	1982
GMK276-2	Ga-Mopedi	Residence	House No 276E	Soil	11.11.04	yes	Trace	RU	1982
GMK276-3	Ga-Mopedi	Residence	House No 276E	Soil	11.11.04	yes	1-3% crocid	RU	1982
GMK276-4	Ga-Mopedi	Residence	House No 276E	Soil	11.11.04	yes	Trace	RU	1982
GMKRS-1	Ga-Mopedi	Rehabilitated Dump	Rehabilitated Mine Dump	Soil	11.11.04	yes	1-3% crocid	RU	2003
GMKRS-2	Ga-Mopedi	Rehabilitated Dump	Rehabilitated Mine Dump	Soil	11.11.04	yes	3-5% crocid	RU	2003
GMKRS-3	Ga-Mopedi	Rehabilitated Dump	Rehabilitated Mine Dump	Soil	11.11.04	yes	Trace	RU	2003
GMKRS-4	Ga-Mopedi	Rehabilitated Dump	Rehabilitated Mine Dump	Soil	11.11.04	yes	5-10% crocid	RU	2003
GMKRS-5	Ga-Mopedi	Rehabilitated Dump	Rehabilitated Mine Dump	Soil	11.11.04	yes	5-10% crocid	RU	2003
GMKRS-6	Ga-Mopedi	Rehabilitated Dump	Rehabilitated Mine Dump	Rocks	11.11.04	yes	Trace	RU	2003
GMKRS-7	Ga-Mopedi	Rehabilitated Dump	Rehabilitated Mine Dump	Rocks	11.11.04	yes	1-3% crocid	RU	2003
GSDKM-4	Ga-Mopedi	Residence	House No 210B	Soil	24.11.04	yes	Trace	RU	1977
GSDKM-5	Ga-Mopedi	Residence	House No 210B	Block	24.11.04	yes	5-10% crocid	RU	1977
GMK277-1	Ga-Mopedi	Residence	House No 277E	Soil	11.11.04	yes	Trace	RU	1990
GMK277-2	Ga-Mopedi	Residence	House No 277E	Soil	11.11.04	yes	1-3% crocid	RU	1990
GMK277-3	Ga-Mopedi	Residence	House No 277E	Soil	11.11.04	yes	1-3% crocid	RU	1990
GMK277-4	Ga-Mopedi	Residence	House No 277E	Soil	11.11.04	yes			1990
GMKH-1	Ga-Mopedi	Open space	Kadibeng Hill	Soil	11.11.04	yes	3-5% crocid	Omni	
GMK324-1	Ga-Mopedi	Residence	House No 324E	Soil	09.11.04	yes	NAD	RU	1981
GMK324-3	Ga-Mopedi	Residence	House No 324E	Soil	09.11.04	yes	Trace	RU	1981
GMK324-4	Ga-Mopedi	Residence	House No 324E	Soil	09.11.04	yes	1-3% crocid	RU	1981
GMD621-1	Ga-Mopedi	Residence	House No 621E	Soil	17.11.04	yes	5-10% crocid	RU	1990
GMD621-2	Ga-Mopedi	Residence	House No 621E	Soil	17.11.04	yes	5-10% crocid	RU	1990

GMD621-3	Ga-Mopedi	Residence	House No 621E	Soil	17.11.04	yes		5-10% crocid	RU	1990
GMD621-4	Ga-Mopedi	Residence	House No 621E	Soil	17.11.04	yes		3-5% crocid	RU	1990
GMS374-1	Ga-Mopedi	Residence	House No 374	Soil	16.11.04	yes		3-5% crocid	RU	1965
GMS374-2	Ga-Mopedi	Residence	House No 374	Soil	16.11.04	yes		10-20% crocid	RU	1965
GMS374-3	Ga-Mopedi	Residence	House No 374	Soil	16.11.04	yes		5-10% crocid	RU	1965
GMS374-4	Ga-Mopedi	Residence	House No 374	Soil	16.11.04	yes		1-3% crocid	RU	1965
GMS374-5	Ga-Mopedi	Residence	House No 374	Soil	16.11.04	yes		3-5% crocid	RU	1965
GMS374-6	Ga-Mopedi	Residence	House No 374	Soil	16.11.04	yes		1-3% crocid	RU	1965
GMS374-7	Ga-Mopedi	Residence	House No 374	Soil	16.11.04	yes		5-10% crocid	RU	1965
GMS374-9	Ga-Mopedi	Residence	House No 374	Foundation slab material	16.11.04	yes		3-5% crocid	RU	1965
GMS374-10	Ga-Mopedi	Residence	House No 374	Rocks	16.11.04	yes		30-40% crocid	RU	1965
GMS374-11	Ga-Mopedi	Residence	House No 374	Building material	16.11.04	yes		100% crocid	RU	1965
GMS374-12	Ga-Mopedi	Residence	House No 374	Building material	16.11.04	yes	yes	1-3% crocid	RU	1965
GMS374-13	Ga-Mopedi	Residence	House No 374	Rocks	16.11.04	yes				1965
GMS374-14	Ga-Mopedi	Residence	House No 374	Rocks	16.11.04	yes		NAD	RU	1965
GMS374-15	Ga-Mopedi	Residence	House No 374	Rocks	16.11.04	yes		5-10% crocid	RU	1965
GMS372-1	Ga-Mopedi	Residence	House No 372	Soil	16.11.04	yes		Trace	RU	1967
GMS372-2	Ga-Mopedi	Residence	House No 372	Soil	16.11.04	yes	yes	Trace	Omni	1967
GMS372-3	Ga-Mopedi	Residence	House No 372	Soil	16.11.04	yes		Trace	RU	1967
GMS372-4	Ga-Mopedi	Residence	House No 372	Soil	16.11.04	yes		1-3% crocid	RU	1967
GMS372-5	Ga-Mopedi	Residence	House No 372	Soil	16.11.04	yes		Trace	RU	1967
GMMC-6	Ga-Mopedi	Church	Methodist Church No 434	Block	16.11.04	yes	yes	1-3% crocid	RU	1999
GMMC-7	Ga-Mopedi	Church	Methodist Church No 434	Mortar	16.11.04	yes		40% crocid	Omni	1999
GMS360-1	Ga-Mopedi	Residence	House No 360	Soil	16.11.04	yes		Trace	RU	1978
GMS360-5	Ga-Mopedi	Residence	House No 360	Block	16.11.04	yes	no	3-5% crocid	RU	1978
GMS360-6	Ga-Mopedi	Residence	House No 360	Foundation slab material	16.11.04	yes	no	5-10% crocid	RU	1978
GMOS-1	Ga-Mopedi	Mine Site	Ga-Mopedi Open Shaft	Soil	16.11.04	yes		10-20% crocid	RU	
GMOS-2	Ga-Mopedi	Mine Site	Ga-Mopedi Open Shaft	Soil	16.11.04	yes		20-30% crocid	RU	
GMOS-3	Ga-Mopedi	Mine Site	Ga-Mopedi Open Shaft	Soil	16.11.04	yes		Undetermined	RU	
GMOS-4	Ga-Mopedi	Mine Site	Ga-Mopedi Open Shaft	Soil	16.11.04	yes		5-10% crocid	RU	
GMOS-5	Ga-Mopedi	Mine Site	Ga-Mopedi Open Shaft	Soil	16.11.04	yes		10-20% crocid	RU	
GMOS-6	Ga-Mopedi	Mine Site	Ga-Mopedi Open Shaft	Rocks	16.11.04	yes		NAD	RU	
GMOS-7	Ga-Mopedi	Mine Site	Ga-Mopedi Open Shaft	Rocks	16.11.04	yes		1-3%	RU	
GMOS-8	Ga-Mopedi	Mine Site	Ga-Mopedi Open Shaft	Rocks	16.11.04	yes		NAD	RU	
GMKSS-1	Ga-Mopedi	School	Khiba Middle School Ga-Mop	Soil	16.11.04	yes		Trace	RU	1971
GMKSS-2	Ga-Mopedi	School	Khiba Middle School Ga-Mop	Soil	16.11.04	yes		Trace	RU	1971
GMKSS-4	Ga-Mopedi	School	Khiba Middle School Ga-Mop	Soil	16.11.04	yes		Trace	RU	1971
GMKSS-5	Ga-Mopedi	School	Khiba Middle School Ga-Mop	Soil	16.11.04	yes	yes	3-5% crocid	Omni	1971

GMKSS-6	Ga-Mopedi	School	Khiba Middle School Ga-Mop	Foundation slab material	16.11.04	yes		5-10% crocid	RU	1971
GMKSS-7	Ga-Mopedi	School	Khiba Middle School Ga-Mop	Block	16.11.04	yes	no	3-5% crocid	RU	1971
GMKSS-8	Ga-Mopedi	School	Khiba Middle School Ga-Mop	Plaster	16.11.04	yes		NAD	RU	1971
GMKSS-9	Ga-Mopedi	School	Khiba Middle School Ga-Mop	Rocks	16.11.04	yes		1-3% crocid	RU	1977
GMD509-2	Ga-Mopedi	Residence	House No 509E	Soil	17.11.04	yes		Trace	RU	1978
GMD509-4	Ga-Mopedi	Residence	House No 509E	Soil	17.11.04	yes		Trace	RU	1978
GMD509-5	Ga-Mopedi	Residence	House No 509E	Foundation slab material	17.11.04	yes	no	5-10% crocid	RU	1978
GMD509-6	Ga-Mopedi	Residence	House No 509E	Block	17.11.04	yes	no	5-10% crocid	RU	1978
GMK302-1	Ga-Mopedi	Residence	House No 302	Roof	18.11.04	yes	no	>50% Crocid&Chrys	RU	
GMK350-1	Ga-Mopedi	Residence	House No 350	Roof	18.11.04	yes		NAD	RU	2003
GMK350-2	Ga-Mopedi	Residence	House No 350	Roof	18.11.04	yes		NAD	RU	2003
GMK350-3	Ga-Mopedi	Residence	House No 350	Roof	18.11.04	yes		>50% Crocid&Chrys	RU	2003
GMD523-5	Ga-Mopedi	Residence	House No 523	Block	17.11.04	yes	no	20-30% crocid	RU	1978
GMD502-4	Ga-Mopedi	Residence	House No 502	Soil	17.11.04	yes		Trace	RU	1983
GMD502-5	Ga-Mopedi	Residence	House No 502	Soil	17.11.04	yes	yes	30-50% crocid	RU	1983
GMTS-1	Ga-Mopedi	Private business	Ga-Mopedi Trading Store	Soil	17.11.04	yes		3-5% crocid	RU	
GMTS-2	Ga-Mopedi	Private business	Ga-Mopedi Trading Store	Soil	17.11.04	yes		100% crocid	RU	
GMTS-4	Ga-Mopedi	Private business	Ga-Mopedi Trading Store	Soil	17.11.04	yes		Trace	RU	
GMD477-4	Ga-Mopedi	Residence	House No 477	Soil	17.11.04	yes		NAD	RU	1979
GMD477-5	Ga-Mopedi	Residence	House No 477	Foundation slab material	17.11.04	yes		1-3% crocid	RU	1979
GMD477-6	Ga-Mopedi	Residence	House No 477	Block	17.11.04	yes		10-20% crocid	RU	1979
GGM1	Gamotsamai	Residence	House No 45	Soil	01.12.04	no		NAD	RU	1976
GGM2	Gamotsamai	Residence	House No 45	Soil	01.12.04	no		NAD	RU	1976
GGM3	Gamotsamai	Residence	House No 45	Soil	01.12.04	no		NAD	RU	1976
GGM4	Gamotsamai	Residence	House No 45	Soil	01.12.04	no		NAD	RU	1976
GGM5	Gamotsamai	Residence	House No 45	Mortar	01.12.04	no		NAD	RU	1976
GGM6	Gamotsamai	Residence	House No 45	Concrete	01.12.04	no		NAD	RU	1976
GGM-AH1	Gamotsamai	Residence	House No 186	Soil	01.12.04	no		Trace	RU	
GGM-AH2	Gamotsamai	Residence	House No 186	Soil	01.12.04	no	yes	Trace	Omni	
GGM-AH4	Gamotsamai	Residence	House No 186	Soil	01.12.04	no		Trace	RU	
GGM-AH5	Gamotsamai	Residence	House No 186	Plaster	01.12.04	no		NAD	RU	
GGM-BM1	Gamotsamai	Residence	House No 111E	Soil	02.12.04	no		NAD	RU	2002
GGM-BM2	Gamotsamai	Residence	House No 111E	Soil	02.12.04	no		NAD	RU	2002
GGM-BM3	Gamotsamai	Residence	House No 111E	Soil	02.12.04	no		NAD	RU	2002
GGM-BM4	Gamotsamai	Residence	House No 111E	Soil	02.12.04	no		NAD	Omni	2002
GGM-IPS1	Gamotsamai	School	Ineeling Primary School	Soil	01.12.04	no		NAD	Omni	1985
GGM-IPS2	Gamotsamai	School	Ineeling Primary School	Soil	01.12.04	no		NAD	Omni	1985

GGM-IPS3	Gamotsamai	School	Ineeling Primary School	Soil	01.12.04	no			NAD	Omni	1985
GGM-IPS4	Gamotsamai	School	Ineeling Primary School	Soil	01.12.04	no			NAD	Omni	1985
GGM-FM1	Gamotsamai	Residence	House No A22	Soil	01.11.04	no			NAD	RU	1998
GGM-FM2	Gamotsamai	Residence	House No A22	Soil	01.11.04	no			Trace	Omni	1998
GGM-FM3	Gamotsamai	Residence	House No A22	Soil	01.11.04	no			NAD	RU	1998
GGM-FM4	Gamotsamai	Residence	House No A22	Soil	01.11.04	no			Trace	RU	1998
GGM-FM5	Gamotsamai	Residence	House No A22	Mortar	01.11.04	no					1998
GGM-FM6	Gamotsamai	Residence	House No A22	Foundation slab material	01.11.04	no			NAD	RU	1998
GGM-JM1	Gamotsamai	Residence	House No 118E	Soil	02.12.04	no			NAD	RU	1975
GGM-JM2	Gamotsamai	Residence	House No 118E	Soil	02.12.04	no			NAD	RU	1975
GGM-JM3	Gamotsamai	Residence	House No 118E	Soil	02.12.04	no			NAD	RU	1975
GGM-JM4	Gamotsamai	Residence	House No 118E	Soil	02.12.04	no			Trace	RU	1975
GGM-JM5	Gamotsamai	Residence	House No 118E	Plaster	02.12.04	no			NAD	RU	1975
GGMG-B1	Gamotsamai	Graveyard	Graveyard	Block	02.12.04	yes		no	3-5% crocid	RU	1998
GGM7	Gamotsamai	Residence	House No 45	Block	01.12.04	yes		no	10-20% crocid	RU	1976
GGM8	Gamotsamai	Residence	House No 45	Ceiling	01.12.04	yes		no	>50% Crocid & Chrys	RU	1976
GGM-AH3	Gamotsamai	Residence	House No 186	Soil	01.12.04	yes			Trace	RU	
GGM-AH6	Gamotsamai	Residence	House No 186	Foundation slab material	01.12.04	yes			>5% crocid	Omni	
GGM-AH7	Gamotsamai	Residence	House No 186	Block	01.12.04	yes		no	Trace	RU	
GGM-BM5	Gamotsamai	Residence	House No 111E	Foundation slab material	02.12.04	yes		yes	10-20% crocid	RU	2002
GGM-IPS5	Gamotsamai	School	Ineeling Primary School	Floor	01.12.04	yes			1-5% crocid	Omni	1985
GGM-AB1	Gamotsamai	Residence	House No 69E	Roof	01.12.04	yes		no	>50% Crocid & Chrys	RU	1999
GGM-EM1	Gamotsamai	Residence	House No 72E	Roof	01.12.04	yes			>10% chry	RU	1985
GGM-FM7	Gamotsamai	Residence	House No A22	Block	01.11.04	yes		no	5-10% crocid	RU	1998
GGM-HB1	Gamotsamai	Residence	House No 70	Roof	01.12.04	yes		no	>50% Crocid & Chrys	RU	1999
GGM-ES1	Gamotsamai	Residence	House No 121E	Ceiling	02.12.04	yes		no	>50% Crocid & Chrys	RU	1998
GGM-ES2	Gamotsamai	Residence	House No 121E	Block	02.12.04	yes		no	3-5% crocid	RU	1998
GGM-JM6	Gamotsamai	Residence	House No 118E	Foundation slab material	02.12.04	yes		no	20-30% crocid	RU	1975
GGM-JM7	Gamotsamai	Residence	House No 118E	Block	02.12.04	yes		no	5-10% crocid	RU	1975
GML40-1	Gasehubane	Residence	House No 40 Gasehubane village	Soil	25.04.05	no			NAD	RU	1990
GML40-2	Gasehubane	Residence	House No 40 Gasehubane village	Soil	25.04.05				NAD	RU	1990
GML40-3	Gasehubane	Residence	House No 40 Gasehubane village	Soil	25.04.05				NAD	RU	1990
GML40-4	Gasehubane	Residence	House No 40 Gasehubane village	Soil	25.04.05				NAD	RU	1990
GML40-5	Gasehubane	Residence	House No 40 Gasehubane village	Block	25.04.05	yes	Poor		3-5% crocid	RU	1990
GMRD-1	Gasehubane	Road	Public Road	Soil	25.04.05						

GDK28-1	Gasehubane	Residence	House No 28H	Soil	25.04.05				NAD	RU	2002
GDK28-2	Gasehubane	Residence	House No 28H	Soil	25.04.05				NAD	RU	2002
GDK28-3	Gasehubane	Residence	House No 28H	Soil	25.04.05				NAD	RU	2002
GDK28-4	Gasehubane	Residence	House No 28H	Soil	25.04.05				NAD	RU	2002
GOK27-1	Gasehubane	Residence	House No A27	Soil	25.04.05				NAD	RU	1992
GOK27-2	Gasehubane	Residence	House No A27	Soil	25.04.05				NAD	RU	1992
GOK27-3	Gasehubane	Residence	House No A27	Soil	25.04.05				NAD	RU	1992
GOK27-4	Gasehubane	Residence	House No A27	Soil	25.04.05				NAD	RU	1992
GOK27-5	Gasehubane	Residence	House No A27	Block	25.04.05		Fair	yes	Trace	RU	1992
GPS-1	Gasehubane	School	Gasehubane Primary School	Soil	25.04.05				Trace	RU	1982
GPS-2	Gasehubane	School	Gasehubane Primary School	Soil	25.04.05				Trace	RU	1982
GPS-3	Gasehubane	School	Gasehubane Primary School	Soil	25.04.05				NAD	RU	1982
GPS-4	Gasehubane	School	Gasehubane Primary School	Soil	25.04.05				NAD	RU	1982
GPS-5	Gasehubane	School	Gasehubane Primary School	Block	25.04.05				3-5% crocid	RU	1982
GPS-6	Gasehubane	School	Gasehubane Primary School	Floor	25.04.05				3-5% crocid	RU	1982
GGL23-1	Gasehubane	Residence	House No B23	Soil	25.04.05	no			NAD	RU	1975
GGL23-2	Gasehubane	Residence	House No B23	Soil	25.04.05	no			NAD	RU	1975
GGL23-3	Gasehubane	Residence	House No B23	Soil	25.04.05	no			Trace	RU	1975
GGL23-4	Gasehubane	Residence	House No B23	Soil	25.04.05	no			NAD	RU	1975
GGL23-5	Gasehubane	Residence	House No B23	Block	25.04.05	yes	Fair		20-30% crocid	RU	1975
GTS14-1	Gasehubane	Residence	House No A14	Soil	25.04.05				3-5% crocid	RU	1968
GTS14-2	Gasehubane	Residence	House No A14	Soil	25.04.05				NAD	RU	1968
GTS14-3	Gasehubane	Residence	House No A14	Soil	25.04.05				Trace	RU	1968
GTS14-4	Gasehubane	Residence	House No A14	Soil	25.04.05				NAD	RU	1968
GTS14-5	Gasehubane	Residence	House No A14	Floor	25.04.05				30-50% crocid	RU	1968
G-JB 37e - 1	Gatshikedi	Residence	Gatshikedi Village	Soil	21.04.05				NAD	RU	1997
G-JB 37e - 2	Gatshikedi	Residence	Gatshikedi Village	Soil	21.04.05				Trace	RU	1997
G-JB 37e - 3	Gatshikedi	Residence	Gatshikedi Village	Soil	21.04.05				Trace	RU	1997
G-JB 37e - 4	Gatshikedi	Residence	Gatshikedi Village	Soil	21.04.05				Trace	RU	1997
G-EL 65e - 1	Gatshikedi	Residence	Gatshikedi Block E H/N 65	Soil	21.04.05				NAD	RU	1986
G-EL 65e - 2	Gatshikedi	Residence	Gatshikedi Block E H/N 65	Soil	21.04.05				NAD	RU	1986
G-EL 65e - 3	Gatshikedi	Residence	Gatshikedi Block E H/N 65	Soil	21.04.05				NAD	RU	1986
G-EL 65e - 4	Gatshikedi	Residence	Gatshikedi Block E H/N 65	Soil	21.04.05				NAD	RU	1986
G-EL 65e - 5	Gatshikedi	Residence	Gatshikedi Block E H/N 65	Block	21.04.05		Fair	no	3-5% crocid	RU	1986
G-TS 40e - 1	Gatshikedi	Residence	Gatshikedi Block E H/N 40E	Soil	21.04.05				NAD	RU	1989
G-TS 40e - 2	Gatshikedi	Residence	Gatshikedi Block E H/N 40E	Soil	21.04.05				NAD	RU	1989
G-TS 40e - 3	Gatshikedi	Residence	Gatshikedi Block E H/N 40E	Soil	21.04.05				NAD	RU	1989
G-TS 40e - 4	Gatshikedi	Residence	Gatshikedi Block E H/N 40E	Soil	21.04.05				NAD	RU	1989

G-TS 40e - 5	Gatshikedi	Residence	Gatshikedi Block E H/N 40E	Foundation	21.04.05		Fair	yes	5-10% crocid	RU	1989
G-MR - 1	Gatshikedi	Road	Gatshikedi Village	Soil	21.04.05				NAD	RU	2000
G-CR - 1	Gatshikedi	Road	Gatshikedi Community Road	Soil	21.04.05				NAD	RU	-
G-DL 90e - 1	Gatshikedi	Residence	Gatshikedi Village H/N 90	Soil	21.04.05				NAD	RU	1972
G-DL 90e - 2	Gatshikedi	Residence	Gatshikedi Village H/N 90	Soil	21.04.05				NAD	RU	1972
G-DL 90e - 3	Gatshikedi	Residence	Gatshikedi Village H/N 90	Soil	21.04.05				NAD	RU	1972
G-DL 90e - 4	Gatshikedi	Residence	Gatshikedi Village H/N 90	Soil	21.04.05				NAD	RU	1972
H2	Heuningvlei	Public Buildings	Heuningvlei Community Hall	Soil	20.10.04	no	Poor		Trace	RU	
H3	Heuningvlei	Public Buildings	Heuningvlei Community Hall	Block	20.10.04	no	Poor		1-5% Crocid	RU	
MMM3	Heuningvlei	Residence	Gamagoy House No 220A	Soil	25.11.04	no			NAD	RU	
MMM4	Heuningvlei	Residence	Gamagoy House No 220A	Soil	25.11.04	no			Trace	RU	
GSA1	Heuningvlei	Road	Gamagou Site	Soil	24.11.04	no	poor		NAD	RU	
GSA2	Heuningvlei	Road	Gamagou Site	Soil	24.11.04	no	poor		NAD	RU	
OFB1	Heuningvlei	Residence	Gamagoy House No 186A	Soil	25.11.04	no			NAD	RU	
OFB2	Heuningvlei	Residence	Gamagoy House No 186A	Foundation slab material	25.11.04	no			NAD	RU	
GMR1	Heuningvlei	Road	Gatsejane Main Road	Soil	30.11.04	no			NAD	RU	
GMR2	Heuningvlei	Road	Gatsejane Main Road	Soil	30.11.04	no			NAD	RU	
GMR3	Heuningvlei	Road	Gatsejane Main Road	Soil	30.11.04	no			NAD	RU	
GMR4	Heuningvlei	Road	Gatsejane Main Road	Soil	30.11.04	no			NAD	RU	
GM1	Heuningvlei	Residence	Gatsejane House No 283	Soil	30.11.04	no			NAD	RU	1980
GM2	Heuningvlei	Residence	Gatsejane House No 283	Soil	30.11.04	no			NAD	RU	1980
OP1	Heuningvlei	Residence	Longaneng House	Soil	25.11.04	no			Trace	RU	
OP3	Heuningvlei	Residence	Longaneng House	Soil	25.11.04	no			NAD	RU	
JJD1	Heuningvlei	Residence	Dilkole House No 183	Soil	25.11.04	no			NAD	RU	
JJD2	Heuningvlei	Residence	Dilkole House No 183	Soil	25.11.04	no			NAD	RU	
VS1	Heuningvlei	Road	Gamagoy	Soil	25.11.04	no			NAD	RU	
VS2	Heuningvlei	Open space	Gamagoy	Soil	25.11.04	no			NAD	RU	
CGS	Heuningvlei	Road	Gatsejane Site	Soil	30.11.04	no					
CGS	Heuningvlei	Open space	Gatsejane Site	Soil	30.11.04	no					
CGS	Heuningvlei	Open space	Gatsejane Site	Soil	30.11.04	no					
KMT1	Heuningvlei	Residence	Heuningvlei House No. 49B	Soil	30.11.04	no			NAD	RU	1990
KMT2	Heuningvlei	Residence	Heuningvlei House No. 49B	Soil	30.11.04	no			NAD	RU	1990
KMT3	Heuningvlei	Residence	Heuningvlei House No. 49B	Soil	30.11.04	no			NAD	RU	1990
KMT4	Heuningvlei	Residence	Heuningvlei House No. 49B	Soil	30.11.04	no			NAD	RU	1990
MM1	Heuningvlei	Open space	Lokaleng No 14	Soil	02.12.04	no			NAD	RU	
MM2	Heuningvlei	Open space	Lokaleng No 14	Soil	02.12.04	no			NAD	RU	
MM3	Heuningvlei	Open space	Lokaleng No 14	Soil	02.12.04	no			NAD	RU	
MM4	Heuningvlei	Open space	Lokaleng No 14	Soil	02.12.04	no			NAD	RU	

IP2	Heuningvlei	Residence	I Phetane	Soil	25.11.04	no	NAD	RU	
IP4	Heuningvlei	Residence	I Phetane	Soil	25.11.04	no	NAD	RU	
TPS1	Heuningvlei	School	Tsoe Primary School	Soil	01.12.04	no	Trace	RU	1980
HFSU1	Heuningvlei	Residence	Home	Soil	01.12.04	no	NAD	RU	1989
HFSU2	Heuningvlei	Residence	Home	Foundation slab material	01.12.04	no	NAD	RU	1989
HFSU3	Heuningvlei	Residence	Home	Block	01.12.04	no	NAD	RU	1989
HFSU4	Heuningvlei	Residence	Home	Block	01.12.04	no	NAD	RU	1989
HFSU5	Heuningvlei	Residence	Home	Soil	01.12.04	no			1989
HFSU6	Heuningvlei	Residence	Home	Soil	01.12.04	no			1989
MAM5	Heuningvlei	Residence	Heuningvlei House No 73	Soil	30.11.04	no	Trace	RU	1991
KBBS1	Heuningvlei	Residence	Home	Soil	24.11.04	no	NAD	RU	
KBBS2	Heuningvlei	Residence	Home	Soil	24.11.04	no	NAD	RU	
KBBS3	Heuningvlei	Residence	Home	Foundation slab material	24.11.04	no	NAD	RU	
TM3	Heuningvlei	Residence	Gamagoy House No 279	Soil	25.11.04	no	NAD	RU	
GAS2	Heuningvlei	Residence	Gamagoy House No 171	Soil	01.12.04	no	NAD	RU	
GAS4	Heuningvlei	Residence	Gamagoy House No 171	Soil	01.12.04	no	NAD	RU	
GAS5	Heuningvlei	Residence	Gamagoy House No 171	Block	01.12.04	no	NAD	RU	
GRM1	Heuningvlei	Residence	Lokaleng House No 12	Soil	02.12.04	no	NAD	RU	
GRM4	Heuningvlei	Residence	Lokaleng House No 12	Block	02.12.04	no	NAD	RU	
LS2-1	Heuningvlei	Open space	Lokaleng	Soil	02.11.04	no	NAD	RU	
LS2-4	Heuningvlei	Open space	Lokaleng	Soil	02.11.04	no	NAD	RU	
LSS1	Heuningvlei	Road	Lokaleng	Soil	02.12.04	no	NAD	RU	
LSS3	Heuningvlei	Road	Lokaleng	Soil	02.12.04	no	NAD	RU	
LSS4	Heuningvlei	Road	Lokaleng	Soil	02.12.04	no	NAD	RU	
HAK1	Heuningvlei	Open space	Heuningvlei Auction kraals	Soil	02.12.04	no	NAD	RU	
HAK2	Heuningvlei	Open space	Heuningvlei Auction kraals	Soil	02.12.04	no	NAD	RU	
HAK3	Heuningvlei	Open space	Heuningvlei Auction kraals	Soil	02.12.04	no	NAD	RU	
HAK4	Heuningvlei	Open space	Heuningvlei Auction kraals	Soil	02.12.04	no	NAD	RU	
SWR1	Heuningvlei	Public Buildings	Longaneng Sedibeng Water Reserv	Soil	07.12.04	no	NAD	RU	
SWR2	Heuningvlei	Public Buildings	Longaneng Sedibeng Water Reserv	Soil	07.12.04	no	NAD	RU	
SWR3	Heuningvlei	Public Buildings	Longaneng Sedibeng Water Reserv	Foundation slab material	07.12.04	no	NAD	RU	
SWR4	Heuningvlei	Public Buildings	Longaneng Sedibeng Water Reserv	Foundation slab material	07.12.04	no	NAD	RU	
SWR5	Heuningvlei	Public Buildings	Longaneng Sedibeng Water Reserv	Soil	07.12.04	no	NAD	RU	
SWR6	Heuningvlei	Public Buildings	Longaneng Sedibeng Water Reserv	Soil	07.12.04	no	NAD	RU	
LVS1	Heuningvlei	Open space	Longaneng Veld Site	Soil	07.12.04	no	NAD	RU	
LVS2	Heuningvlei	Open space	Longaneng Veld Site	Soil	07.12.04	no	NAD	RU	
LVS3	Heuningvlei	Open space	Longaneng Veld Site	Soil	07.12.04	no	Trace	RU	
SB2	Heuningvlei	Residence	Longaneng S Barapami Home	Soil	07.12.04	no	NAD	RU	1992

MCM1	Heuningvlei	Residence	Longaneng Matotwe Home	Soil	08.12.04	no		Trace	Omni	1940
MCM2	Heuningvlei	Residence	Longaneng Matotwe Home	Soil	08.12.04	no		Trace	Omni	1940
MCM3	Heuningvlei	Residence	Longaneng Matotwe Home	Soil	08.12.04	no		Trace	Omni	1940
MCM4	Heuningvlei	Residence	Longaneng Matotwe Home	Soil	08.12.04	no		Trace	Omni	1940
MCM5	Heuningvlei	Residence	Longaneng Matotwe Home	Soil	08.12.04	no		NAD	Omni	1940
MCM6	Heuningvlei	Residence	Longaneng Matotwe Home	Soil	08.12.04	no		Trace	RU	
TMT1	Heuningvlei	Residence	Longaneng House No D20	Soil	08.12.04	no		NAD		1987
TMT3	Heuningvlei	Residence	Longaneng House No D20	Foundation slab material	08.12.04	no		NAD		1987
TMT4	Heuningvlei	Residence	Longaneng House No D20	Soil	08.12.04	no		NAD		1987
LGL2	Heuningvlei	Residence	Longaneng House No D19	Soil	07.12.04	no		NAD	RU	
LGL3	Heuningvlei	Residence	Longaneng House No D19	Soil	07.12.04	no		NAD	RU	
LGL4	Heuningvlei	Residence	Longaneng House No D19	Foundation slab material	07.12.04	no		NAD	RU	
LGL5	Heuningvlei	Residence	Longaneng House No D19	Soil	07.12.04	no		NAD	RU	
GMB2	Heuningvlei	Residence	Longaneng B Mushoeu Home	Soil	09.12.04	no		Trace	Omni	1987
GMB3	Heuningvlei	Residence	Longaneng B Mushoeu Home	Soil	09.12.04	no		Trace	Omni	1987
GMB4	Heuningvlei	Residence	Longaneng B Mushoeu Home	Soil	09.12.04	no		Trace	Omni	1987
OJM1	Heuningvlei	Residence	Longaneng House No D25	Soil	08.12.04	no		2% crocid	Omni	1993
OJM2	Heuningvlei	Residence	Longaneng House No D25	Soil	08.12.04	no		Trace	Omni	1993
OJM3	Heuningvlei	Residence	Longaneng House No D25	Foundation slab material	08.12.04	no	yes	Trace	Omni	1993
OJM4	Heuningvlei	Residence	Longaneng House No D25	Block	08.12.04	no	yes	NAD	Omni	1993
LRS1	Heuningvlei	Road	Longaneng Road Surface	Soil	09.12.04	no		Trace	Omni	
LRS2	Heuningvlei	Road	Longaneng Road Surface	Soil	09.12.04	no		Trace	Omni	
LRS3	Heuningvlei	Road	Longaneng Road Surface	Soil	09.12.04	no		Trace	Omni	
LRS4	Heuningvlei	Road	Longaneng Road Surface	Soil	09.12.04	no		Trace	Omni	
MFM1	Heuningvlei	Residence	Longaneng House No D340	Soil	09.12.04	no		Trace	Omni	1989
MFM2	Heuningvlei	Residence	Longaneng House No D340	Soil	09.12.04	no		Trace	Omni	1989
MFM3	Heuningvlei	Residence	Longaneng House No D340	Soil	09.12.04	no		Trace	Omni	1989
MFM4	Heuningvlei	Residence	Longaneng House No D340	Block	09.12.04	no	no	NAD	Omni	1989
MRT1	Heuningvlei	Residence	Longaneng House No D24	Soil	08.12.04	no		Trace	Omni	1987
MRT2	Heuningvlei	Residence	Longaneng House No D24	Soil	08.12.04	no		Trace	Omni	1987
MRT4	Heuningvlei	Residence	Longaneng House No D24	Building material	08.12.04	no	yes	5% crocid	Omni	1987
MAK1	Heuningvlei	Residence	Longaneng Kgololo House	Soil	08.12.04	no		NAD	RU	1997
MAK2	Heuningvlei	Residence	Longaneng Kgololo House	Soil	08.12.04	no		NAD	RU	1997
MAK3	Heuningvlei	Residence	Longaneng Kgololo House	Soil	08.12.04	no		NAD	RU	1997
MAK4	Heuningvlei	Residence	Longaneng Kgololo House	Soil	08.12.04	no		NAD	RU	1997
HB3-2	Heuningvlei	Residence	Heuningvlei	Soil	11.11.04	no		Traceolite	RU	
HR1A	Heuningvlei	Residence	Heuningvlei	Soil	11.11.04	no		1% crocid	RU	
DEM2	Heuningvlei	Residence	GMK House No 430	Soil	10.11.04	no		NAD	RU	1991

DEM4	Heuningvlei	Residence	GMK House No 430	Block	10.11.04	no	NAD	RU	1991
PS1	Heuningvlei	Open space	Gammokwana	Soil	10.11.04	no	NAD	RU	
MPS1	Heuningvlei	School	MP School	Soil	10.11.04	no	Trace	RU	2003
MPS2	Heuningvlei	School	MP School	Soil	10.11.04	no	Trace	Omni	2003
MPS3	Heuningvlei	School	MP School	Soil	10.11.04	no	NAD	RU	2003
MPS5	Heuningvlei	School	MP School	Soil	10.11.04	no	Trace	Omni	2003
OWO2	Heuningvlei	Open space	Old Wall Oven	Block	11.11.04	no	NAD	RU	
LMM2	Heuningvlei	Residence	Gamokwana House No 362	Soil	09.11.04	no	NAD	RU	1950
SELC1	Heuningvlei	Residence	Gamokwana Road	Soil	09.11.04	no	NAD	RU	1998
SELC2	Heuningvlei	Residence	Gamokwana Road	Foundation slab material	09.11.04	no	NAD	RU	1998
SELC3	Heuningvlei	Residence	Gamokwana Road	Soil	09.11.04	no	Trace	Omni	1998
GMK2	Heuningvlei	Road	Gamokwana Road	Soil	09.11.04	no			
BL2	Heuningvlei	Residence	Gamokwana House No 410E	Soil	09.11.04	no	NAD	RU	1970
BL3	Heuningvlei	Residence	Gamokwana House No 410E	Soil	09.11.04	no	NAD	RU	1970
HPS3	Heuningvlei	Residence	HP Station	Soil	16.11.04	no	NAD	RU	
HPS4	Heuningvlei	Residence	HP Station	Soil	16.11.04	no			
BMAM	Heuningvlei	Residence	House No 425	Soil	10.11.04	no			
SNS1	Heuningvlei	School	SN School Gammakwana Rd	Soil	10.11.04	no	NAD	RU	
SNS2	Heuningvlei	School	SN School Gammakwana Rd	Soil	10.11.04	no	NAD	RU	
TBP4	Heuningvlei	Residence	House No 313	Soil	23.11.04	no	NAD	RU	1985
EMM1	Heuningvlei	Residence	House No D299	Soil	23.11.04	no	NAD	RU	1991
EMM2	Heuningvlei	Residence	House No D299	Soil	23.11.04	no	NAD	RU	1991
EMM4	Heuningvlei	Residence	House No D299	Soil	23.11.04	no	NAD	RU	1991
PM1	Heuningvlei	Residence	Mooketsi House	Soil	16.11.04	no	NAD	RU	
PM2	Heuningvlei	Residence	Mooketsi House	Soil	16.11.04	no	NAD	RU	
ERP1	Heuningvlei	Residence	House No 338	Block	23.11.04	no	NAD	RU	1990s
ERP2	Heuningvlei	Residence	House No 338	Soil	23.11.04	no	NAD	RU	1990s
ERP3	Heuningvlei	Residence	House No 338	Soil	23.11.04	no	NAD	RU	1990s
ERP4	Heuningvlei	Residence	House No 338	Foundation slab material	23.11.04	no	NAD	RU	1990s
HC1	Heuningvlei	Hospital/Clinic	Heuningvlei Clinic	Soil	16.11.04	no	Trace	RU	
HC2	Heuningvlei	Hospital/Clinic	Heuningvlei Clinic	Soil	16.11.04	no	Trace	RU	
HC3	Heuningvlei	Hospital/Clinic	Heuningvlei Clinic	Soil	16.11.04	no	Trace	RU	
HQ1	Heuningvlei	Residence	House No 488	Soil	16.11.04	no	Trace	RU	
OHW2	Heuningvlei	Residence	Hostel Roundables	Soil	11.11.04	no	Trace	RU	
EW1	Heuningvlei	Graveyard	Graveyard	Soil	17.11.04	no	NAD	RU	
EW2	Heuningvlei	Graveyard	Graveyard	Soil	17.11.04	no	NAD	RU	
EP1	Heuningvlei	Open space	Entrance to Passade	Soil	18.11.04	no	Trace	RU	
MSS1	Heuningvlei	Residence	GMK House No 427	Soil	10.11.04	no	NAD	RU	1990

MSS4	Heuningvlei	Residence	GMK House No 427	Soil	10.11.04	no			NAD	RU	1990
OB1	Heuningvlei	Residence	GMK House No 388	Soil	09.11.04	no			NAD	RU	
OB4	Heuningvlei	Residence	GMK House No 388	Soil	09.11.04	no			NAD	RU	
RCC2	Heuningvlei	Church	RC Church	Soil	16.11.04	no			NAD	RU	1970s
RCC3	Heuningvlei	Church	RC Church	Soil	16.11.04	no			NAD	RU	1970s
RCC4	Heuningvlei	Church	RC Church	Soil	16.11.04	no			NAD	RU	1970s
GG1	Heuningvlei	Residence	Home	Soil	16.11.04	no			Trace	RU	1993
HPW1a	Heuningvlei	Public Buildings	HP Works	Soil	17.11.04	no			NAD	RU	1990
HPW1b	Heuningvlei	Public Buildings	HP Works	Soil	17.11.04	no			NAD	RU	1990
HPW1c	Heuningvlei	Public Buildings	HP Works	Soil	17.11.04	no			NAD	RU	1990
HPW2	Heuningvlei	Public Buildings	HP Works	Soil	17.11.04	no			NAD	RU	1990
HPW3	Heuningvlei	Public Buildings	HP Works	Soil	17.11.04	no			NAD	RU	1990
HPW4	Heuningvlei	Public Buildings	HP Works	Soil	17.11.04	no			NAD	RU	1990
EM1	Heuningvlei	Residence	GMK House No 392	Soil	09.11.04	no			NAD	RU	
EM2	Heuningvlei	Residence	GMK House No 392	Soil	09.11.04	no			NAD	RU	
RDS1	Heuningvlei	Residence	RD Shop	Soil	16.11.04	no			NAD	RU	
RDS2	Heuningvlei	Residence	RD Shop	Soil	16.11.04	no			NAD	RU	
CTH3	Heuningvlei	Public Buildings	Tribal Hall	Block	24.11.04	no		no	1-3% crocid	RU	
CTH7	Heuningvlei	Public Buildings	Tribal Hall	Foundation slab material	24.11.04	no			NAD	RU	
CTH8	Heuningvlei	Public Buildings	Tribal Hall	Foundation slab material	24.11.04	no		no	3-5% crocid	Omni	
CTH9	Heuningvlei	Public Buildings	Tribal Hall	Block	24.11.04	no		no	Trace	RU	
PN2	Heuningvlei	Open space	Pan	Soil	18.11.04	no			Trace	RU	
GGK2	Heuningvlei	Residence	Gamagoy House	Soil	23.11.04	no			Trace	RU	
GGK3	Heuningvlei	Residence	Gamagoy House	Soil	23.11.04	no			Trace	RU	
GGK4	Heuningvlei	Residence	Gamagoy House	Soil	23.11.04	no			NAD	RU	
BA/TA1	Heuningvlei	Public Buildings	TA 489	Soil	11.11.04	no			NAD	RU	
BA/TA2	Heuningvlei	Public Buildings	TA 489	Soil	11.11.04	no			Trace	RU	
BA/TA2/4	Heuningvlei	Public Buildings	TA 489	Soil	11.11.04	no					
SR 1	Heuningvlei	Road	State Road	Soil	18.11.04	no			Trace	RU	
ST1	Heuningvlei	Road	State Road No 1	Soil	18.11.04	no			1-3% crocid	RU	
CP1	Heuningvlei	Residence	Chief's Palace	Foundation slab material	18.11.04	no		yes	Trace	RU	
CP2	Heuningvlei	Residence	Chief's Palace	Bricks	18.11.04	no	Poor	yes	Trace	RU	
CP3	Heuningvlei	Residence	Chief's Palace	Block	18.11.04	no			NAD	RU	
CP4	Heuningvlei	Residence	Chief's Palace	Soil	18.11.04	no			NAD	RU	
CP5	Heuningvlei	Residence	Chief's Palace	Soil	18.11.04	no			NAD	RU	
OBG1	Heuningvlei	Residence	Gamagoy House No 253	Soil	23.11.04	no			NAD	RU	
OBG2	Heuningvlei	Residence	Gamagoy House No 253	Soil	23.11.04	no			Trace	RU	
OBG3	Heuningvlei	Residence	Gamagoy House No 253	Soil	23.11.04	no			Trace	RU	

BMCT1	Heuningvlei	Residence	Gamagoy House No 287	Soil	24.11.04	no			Trace	RU	2002
BMCT2	Heuningvlei	Residence	Gamagoy House No 287	Soil	24.11.04	no			NAD	RU	2002
BMCT3	Heuningvlei	Residence	Gamagoy House No 287	Block	24.11.04	no		no	Trace	RU	2002
BMCT4	Heuningvlei	Residence	Gamagoy House No 287	Foundation slab material	24.11.04	no			NAD	RU	2002
SG1	Heuningvlei	Open space	Soccer Ground	Soil	23.11.04	no			NAD	RU	
SG2	Heuningvlei	Open space	Soccer Ground	Soil	23.11.04	no			NAD	RU	
SG3	Heuningvlei	Open space	Soccer Ground	Soil	23.11.04	no			NAD	RU	
RM2	Heuningvlei	Residence	Gamagoy House No 292	Foundation slab material	17.11.04	no			NAD	RU	
RM3	Heuningvlei	Residence	Gamagoy House No 292	Soil	17.11.04	no			NAD	RU	
RM4	Heuningvlei	Residence	Gamagoy House No 292	Soil	17.11.04	no			NAD	RU	
H1	Heuningvlei	Public Buildings	Heuningvlei Community Hall	Soil	20.10.04	yes	Poor		Trace	RU	
H5	Heuningvlei	School	Heuningvlei Tsoe Primary Sch	Block	20.10.04	yes	Poor		>5% crocid	RU	
H6	Heuningvlei	School	Heuningvlei Tsoe Primary Sch	Soil	20.10.04	yes	Poor		Trace	RU	
H10	Heuningvlei	School	Heuningvlei Tsoe Primary Sch	Mortar	20.10.04	yes	Poor		>5% crocid	RU	
H20	Heuningvlei	Road	Road to Butte Mine	Soil	20.10.04	yes	Poor		20-30%	RU	
MMM1	Heuningvlei	Residence	Gamagoy House No 220A	Foundation slab material	25.11.04	yes	Poor	yes	5-10% crocid	RU	
MMM2	Heuningvlei	Residence	Gamagoy House No 220A	Block	25.11.04	yes		no	3-5% crocid	RU	
GSA3	Heuningvlei	Open space	Gamagou Site	Soil	24.11.04	yes	Poor		NAD	RU	
GM3	Heuningvlei	Residence	Gatsejane House No 283	Bricks	30.11.04	yes	Fair	yes	1-3% crocid	RU	1980
GM4	Heuningvlei	Residence	Gatsejane House No 283	Bricks	30.11.04	yes	Fair	yes	3-5% crocid	RU	1980
OP2	Heuningvlei	Residence	Longaneng House	Block	25.11.04	yes			10% crocid	Omni	
OP4	Heuningvlei	Residence	Longaneng House	Block	25.11.04	yes			3-5%		
CGS	Heuningvlei	Open space	Gatsejane Site	Soil	30.11.04	yes					
IP1	Heuningvlei	Residence	I Phetane	Bricks	25.11.04	yes		yes	3-5% crocid	RU	
IP3	Heuningvlei	Residence	I Phetane	Bricks	25.11.04	yes			3-5% crocid	RU	
TPS2	Heuningvlei	School	Tsoe Primary School	Soil	01.12.04	yes			1-3%	RU	1980
TPS3	Heuningvlei	School	Tsoe Primary School	Foundation slab material	01.12.04	yes		no	1-3%	RU	1980
TPS4	Heuningvlei	School	Tsoe Primary School	Block	01.12.04	yes		yes	1-3%	RU	1980
TPS5	Heuningvlei	School	Tsoe Primary School	Building Material	01.12.04	yes		yes	3-5%	RU	1980
TPS6	Heuningvlei	School	Tsoe Primary School	Soil	01.12.04	yes			1-3%	RU	1980
TPS7	Heuningvlei	School	Tsoe Primary School	Building Material	01.12.04	yes		no	3-5%	RU	1980
TPS8	Heuningvlei	School	Tsoe Primary School	Soil	01.12.04	yes			Trace	RU	1980
MAM1	Heuningvlei	Residence	Heuningvlei House No 73	Soil	30.11.04	yes			NAD	RU	1991
MAM2	Heuningvlei	Residence	Heuningvlei House No 73	Building Material	30.11.04	yes		no	1-3%	RU	1991
MAM3	Heuningvlei	Residence	Heuningvlei House No 73	Block	30.11.04	yes		yes	3-5%	RU	1991
MAM4	Heuningvlei	Residence	Heuningvlei House No 73	Foundation slab material	30.11.04	yes		no	1-3%	RU	1991
MAMTS1	Heuningvlei	Private business	Tuck Shop	Foundation slab material	30.11.04	yes		no	5-10%	RU	1991
MAMTS2	Heuningvlei	Private business	Tuck Shop	Block	30.11.04	yes		no	3-5%	RU	1991

MAMBS3	Heuningvlei	Private business	Bottle Store	Soil	30.11.04	yes			Trace	RU	1991
MAMBS4	Heuningvlei	Private business	Bottle Store	Soil	30.11.04	yes			Trace	RU	1991
TM1	Heuningvlei	Residence	Gamagoy House No 279	Soil	25.11.04	yes			10-15%	RU	
TM2	Heuningvlei	Residence	Gamagoy House No 279	Bricks	25.11.04	yes			1-3%	RU	
TM4	Heuningvlei	Residence	Gamagoy House No 279	Soil	25.11.04	yes			Trace	RU	
TM5	Heuningvlei	Residence	Gamagoy House No 279	Foundation slab material	25.11.04	yes					
GAS1	Heuningvlei	Residence	Gamagoy House No 171	Foundation slab material	01.12.04	yes			1-3%	RU	1980
GAS3	Heuningvlei	Residence	Gamagoy House No 171	Soil	01.12.04	yes			NAD	RU	
GAS6	Heuningvlei	Residence	Gamagoy House No 171	Block	01.12.04	yes		yes	1-3%	RU	
GAS7	Heuningvlei	Residence	Gamagoy House No 171	Bricks	01.12.04	yes		yes	3-5%	RU	
GRM2	Heuningvlei	Residence	Lokaleng House No 12	Soil	02.12.04	yes			NAD	RU	
GRM3	Heuningvlei	Residence	Lokaleng House No 12	Building Material	02.12.04	yes	Poor	no	1-3%	RU	
LS2-2	Heuningvlei	Open space	Lokaleng	Soil	02.11.04	yes			NAD	RU	
LS2-3	Heuningvlei	Open space	Lokaleng	Soil	02.11.04	yes			NAD	RU	
LSS2	Heuningvlei	Road	Lokaleng	Soil	02.12.04	yes			NAD	RU	
SB1	Heuningvlei	Residence	Longaneng S Barapami Home	Soil	07.12.04	yes			NAD	RU	1992
MCM7	Heuningvlei	Residence	Longaneng Matotwe Home	Building Material	08.12.04	yes		no	10% crocid	Omni	
TMT2	Heuningvlei	Residence	Longaneng House No D20	Building Material	08.12.04	yes			5-10%		1987
LGL1	Heuningvlei	Residence	Longaneng House No D19	Block	07.12.04	yes			3-5%	RU	
GMB1	Heuningvlei	Residence	Longaneng B Mushoeu Home	Soil	09.12.04	yes			Trace	Omni	1987
MRT3	Heuningvlei	Residence	Longaneng House No D24	Foundation slab material	08.12.04	yes		yes	15% crocid	Omni	1987
HB3-1	Heuningvlei	Residence	Heuningvlei	Block	11.11.04	yes			30% crocid	Omni	
HB3-3	Heuningvlei	Residence	Heuningvlei	Soil	11.11.04	yes			1% crocid	RU	
HR1B	Heuningvlei	Residence	Heuningvlei Roundables	Soil	11.11.04	yes			1% crocid	RU	
HR2	Heuningvlei	Residence	Heuningvlei Roundables	Block	11.11.04	yes	Poor		3-5% crocid	RU	
DEM1	Heuningvlei	Residence	GMK House No 430	Block	10.11.04	yes			1-3% crocid	RU	1991
DEM3	Heuningvlei	Residence	GMK House No 430	Block	10.11.04	yes			1-3% crocid	RU	1991
DS1	Heuningvlei	Open space	Old Asbestos Wall	Block	11.11.04	yes			25%+ crocid	RU	
DS2	Heuningvlei	Open space	Old Asbestos Wall	Block	11.11.04	yes			25%+ crocid	RU	
DS3	Heuningvlei	Open space	Old Asbestos Wall	Foundation slab material	11.11.04	yes					
PS2	Heuningvlei		Gammokwana	Bricks	10.11.04	yes			1% crocid	RU	
GCR1	Heuningvlei	Residence	Ramotou's House	Soil	11.11.04	yes			Traceolite	RU	
GCR2	Heuningvlei	Residence	Ramotou's House	Soil	11.11.04	yes			10-15% crocid	RU	
GCR3	Heuningvlei	Residence	Ramotou's House	Block	11.11.04	yes			1-3% crocid	RU	
MPS4	Heuningvlei	School	MP School	Soil	10.11.04	yes			3-5% crocid	RU	2003
OWO1	Heuningvlei		Old Wall Oven	Foundation slab material	11.11.04	yes			1% crocid	RU	
OWO3	Heuningvlei		Old Wall Oven	Roofing	11.11.04	yes			5-10% crocid	RU	
LMM1	Heuningvlei	Residence	Gamokwana House No 362	Soil	09.11.04	yes			Traceolite	RU	1950

GMK1	Heuningvlei	Road	Gamokwana Road	Soil	09.11.04	yes			Trace	RU	
BL1	Heuningvlei	Residence	Gamokwana House No 410E	Soil	09.11.04	yes			Trace-crocid	RU	1970
HPS1	Heuningvlei	Public Buildings	Police Station	Soil	16.11.04	yes			Trace-crocid	RU	
HPS2	Heuningvlei	Public Buildings	Police Station	Soil	16.11.04	yes			Trace-crocid	RU	
HQTS-1	Heuningvlei	Private business	Heuningvlei Quarters Tuck Shop	Soil	16.11.04	yes			5-10% crocid	RU	
HQTS-2	Heuningvlei	Private business	Heuningvlei Quarters Tuck Shop	Soil	16.11.04	yes			Trace	RU	
HPO1	Heuningvlei	Post Office	Post Office	Soil	17.11.04	yes			NAD	RU	1990
BMAM	Heuningvlei	Residence	House No 425	Soil	10.11.04	yes			Trace	RU	
BMAM	Heuningvlei	Residence	House No 425	Soil	10.11.04	yes			Trace	RU	
BMAM	Heuningvlei	Residence	House No 425	Soil	10.11.04	yes			Trace	RU	
TBP1	Heuningvlei	Residence	House No 313	Foundation slab material	23.11.04	yes			3-5% crocid	RU	1985
TBP2	Heuningvlei	Residence	House No 313	Block	23.11.04	yes			3-5% crocid	RU	1985
TBP3	Heuningvlei	Residence	House No 313	Block	23.11.04	yes			3-5% crocid	RU	1985
EMM3	Heuningvlei	Residence	House No D299	Bricks	23.11.04	yes			1-3% crocid	Omni	1991
HQ2	Heuningvlei	Residence	House No 488	Soil	16.11.04	yes			1-3% crocid	RU	
MCP1	Heuningvlei	Public Buildings	Motswedi Co-op	Foundation slab material	11.11.04	yes			5-10% crocid	RU	
MCP2	Heuningvlei	Public Buildings	Motswedi Co-op	Soil	11.11.04	yes			1-3% crocid	RU	
PS1	Heuningvlei	Open space	P. Site	Soil	11.11.04	yes			Trace	RU	
OHW1	Heuningvlei	Residence	Hostel Roundables	Block	11.11.04	yes			10-15% crocid	RU	
MSS2	Heuningvlei	Residence	GMK House No 427	Block	10.11.04	yes		yes	1-3% crocid	RU	1990
MSS3	Heuningvlei	Residence	GMK House No 427	Block	10.11.04	yes		yes	1-3% crocid	RU	1990
OB2	Heuningvlei	Residence	GMK House No 388	Block	09.11.04	yes	Fair	yes	3-5% crocid	RU	
OB3	Heuningvlei	Residence	GMK House No 388	Bricks	09.11.04	yes	Fair	yes	1-3% crocid	RU	
OPS1	Heuningvlei	School	OP School	Soil	16.11.04	yes			Trace	RU	1972
OPS2	Heuningvlei	School	OP School	Soil	16.11.04	yes			Trace	RU	1972
OPS3	Heuningvlei	School	OP School	Foundation slab material	16.11.04	yes		yes	10-30% crocid	RU	1972
OPS4	Heuningvlei	School	OP School	Block	16.11.04	yes		no	5% crocid	RU	1972
RCC1	Heuningvlei	Church	RC Church	Bricks	16.11.04	yes		yes	5-10% crocid	RU	1970s
SNTA1	Heuningvlei	Public Buildings	TA Building	Soil	16.11.04	yes			30-40% crocid	RU	
SNTA2	Heuningvlei	Public Buildings	TA Building	Soil	16.11.04	yes			3-5% crocid	RU	
GG2	Heuningvlei	Residence	Home	Foundation slab material	16.11.04	yes		yes	5-10% crocid	RU	1993
CTH1	Heuningvlei	Public Buildings	Tribal Hall	Soil	24.11.04	yes			1-3% crocid	RU	
CTH2	Heuningvlei	Public Buildings	Tribal Hall	Soil	24.11.04	yes			1-3% crocid	RU	
CTH4	Heuningvlei	Public Buildings	Tribal Hall	Block	24.11.04	yes		no	1-3% crocid	RU	
CTH5	Heuningvlei	Public Buildings	Tribal Hall	Foundation slab material	24.11.04	yes		no	Trace	RU	
CTH10	Heuningvlei	Public Buildings	Tribal Hall	Block	24.11.04	yes		no	1-3% crocid	RU	
SW1A	Heuningvlei	Public Buildings	Sedibeng Water	Soil	11.11.04	yes			5-10% crocid	RU	
SW1B	Heuningvlei	Public Buildings	Sedibeng Water	Soil	11.11.04	yes			1-3%	RU	

SW2A	Heuningvlei	Public Buildings	Sedibeng Water	Soil	11.11.04	yes			Trace	RU	
SW2B	Heuningvlei	Public Buildings	Sedibeng Water	Soil	11.11.04	yes			3-5% crocid	RU	
SW2C	Heuningvlei	Public Buildings	Sedibeng Water	Soil	11.11.04	yes			Trace	RU	
SW3	Heuningvlei	Public Buildings	Sedibeng Water	Block	11.11.04	yes			3-5%	RU	
SW3B	Heuningvlei	Public Buildings	Sedibeng Water	Block	11.11.04	yes			3-5%	RU	
SW4	Heuningvlei	Public Buildings	Sedibeng Water	Soil	11.11.04	yes			Trace	RU	
SW4B	Heuningvlei	Public Buildings	Sedibeng Water	Soil	11.11.04	yes			Trace	RU	
SW5	Heuningvlei	Public Buildings	Sedibeng Water	Soil	11.11.04	yes			1-3%	RU	
SW5B	Heuningvlei	Public Buildings	Sedibeng Water	Soil	11.11.04	yes			Trace	RU	
SW6	Heuningvlei	Public Buildings	Sedibeng Water	Soil	11.11.04	yes			Trace	RU	
PN1	Heuningvlei	Open space	Pan	Soil	18.11.04	yes			1-3% Crocid & Amos	RU	
GGK1	Heuningvlei	Residence	Gamagoy House	Block	23.11.04	yes		no	3-5% crocid	RU	
GGK5	Heuningvlei	Residence	Gamagoy House	Foundation slab material	23.11.04	yes		no	1-3% crocid	RU	
BA/TA3	Heuningvlei	Public Buildings	TA 489	Foundation slab material	11.11.04	yes		no	1-3% crocid	RU	
RM1	Heuningvlei	Residence	Gamagoy House No 292	Block	17.11.04	yes					
H4	Heuningvlei	Public Buildings	Heuningvlei Community Hall	Foundation slab material	20.10.04		Poor				
H7	Heuningvlei	School	Heuningvlei Tsoe Primary Sch	Soil	20.10.04		Poor		NAD	RU	
H8	Heuningvlei	School	Heuningvlei Tsoe Primary Sch	Soil	20.10.04		Poor				
H9	Heuningvlei	School	Heuningvlei Tsoe Primary Sch	Soil	20.10.04		Poor		Trace	RU	
MCR - 1	Magobing	Road	Magobing Village	Soil	13.04.05				Trace	RU	-
MCR - 2	Magobing	Road	Magobing Village	Soil	13.04.05				NAD	RU	-
MCR - 3	Magobing	Road	Magobing Village	Soil	13.04.05				Trace	RU	-
M-RM 83a - 1	Magobing	Residence	Magobing Block A	Soil	13.04.05				Trace	RU	1993
M-RM 83a - 2	Magobing	Residence	Magobing Block A	Soil	13.04.05				Trace	RU	1993
M-RM 83a - 3	Magobing	Residence	Magobing Block A	Soil	13.04.05				Trace	RU	1993
M-RM 83a - 4	Magobing	Residence	Magobing Block A	Soil	13.04.05				NAD	RU	1993
M-RM 83a - 5	Magobing	Residence	Magobing Block A	Block	13.04.05		Poor		Trace	RU	1993
M-RM 83a - 6	Magobing	Residence	Magobing Block A	Floor	13.04.05		Poor	yes	5-10% crocid	RU	1993
MPS - 76 - 1	Magobing	School	Magobing Primary School	Soil	13.04.05				NAD	RU	-
MPS - 76 - 2	Magobing	School	Magobing Primary School	Soil	13.04.05				NAD	RU	-
MPS - 76 - 3	Magobing	School	Magobing Primary School	Soil	13.04.05				NAD	RU	-
MPS - 76 - 4	Magobing	School	Magobing Primary School	Soil	13.04.05				NAD	RU	-
MPS - 76 - 5	Magobing	School	Magobing Primary School	Block	13.04.05		Poor	no	5-10% crocid	RU	-
M-ZP 57a - 1	Magobing	Residence	Magobing Block	Soil	13.04.05				Trace	RU	1997
M-ZP 57a - 2	Magobing	Residence	Magobing Block	Soil	13.04.05				NAD	RU	1997

M-ZP 57a - 3	Magobing	Residence	Magobing Block	Soil	13.04.05			Trace	RU	1997
M-ZP 57a - 4	Magobing	Residence	Magobing Block	Soil	13.04.05			Trace	RU	1997
M-ZP 57a - 5	Magobing	Residence	Magobing Block	Block	13.04.04	Poor	no	20-30% crocid	RU	1997
M-LP 11a - 1	Magobing	Residence	Magobing Block A H/N 11A	Soil	13.04.05			NAD	RU	1980
M-LP 11a - 2	Magobing	Residence	Magobing Block A H/N 11A	Soil	13.04.05			NAD	RU	1980
M-LP 11a - 3	Magobing	Residence	Magobing Block A H/N 11A	Soil	13.04.05			NAD	RU	1980
M-LP 11a - 4	Magobing	Residence	Magobing Block A H/N 11A	Soil	13.04.05			NAD	RU	1980
M-LP 11a - 5	Magobing	Residence	Magobing Block A H/N 11A	Block	13.04.05	Fair	yes	10-20% crocid	RU	1980
M-SN 62a - 1	Magobing	Residentail	Magobing Block A H/N 62A	Soil	13.04.05			Trace	RU	1984
M-SN 62a - 2	Magobing	Residentail	Magobing Block A H/N 62A	Soil	13.04.05			Trace	RU	1984
M-SN 62a - 3	Magobing	Residentail	Magobing Block A H/N 62A	Soil	13.04.05			Trace	RU	1984
M-SN 62a - 4	Magobing	Residentail	Magobing Block A H/N 62A	Soil	13.04.05			Trace	RU	1984
M-SN 62a - 5	Magobing	Residentail	Magobing Block A H/N 62A	Block	13.04.05	Poor	yes	5-10% crocid	RU	1984
M-BL a - 1	Magobing	Residentail	Magobing Village	Soil	13.04.05			NAD	RU	1998
M-BL a - 2	Magobing	Residentail	Magobing Village	Soil	13.04.05			NAD	RU	1998
M-BL a - 3	Magobing	Residentail	Magobing Village	Soil	13.04.05			Trace	RU	1998
M-BL a - 4	Magobing	Residentail	Magobing Village	Soil	13.04.05			NAD	RU	1998
M-BL a - 5	Magobing	Residentail	Magobing Village	Block	13.04.05	Poor	yes	5-10% crocid	RU	1998
M-GS 10a - 1	Magobing	Residentail	Magobing Block A	Soil	13.04.05			Trace	RU	2003
M-GS 10a - 2	Magobing	Residentail	Magobing Block A	Soil	13.04.05			Trace	RU	2003
M-GS 10a - 3	Magobing	Residentail	Magobing Block A	Soil	13.04.05			NAD	RU	2003
M-GS 10a - 4	Magobing	Residentail	Magobing Block A	Soil	13.04.05			Trace	RU	2003
M-GS 10a - 5	Magobing	Residentail	Magobing Block A	Block	13.04.05	Poor	no	5-10% crocid	RU	2003
M-MD 81a - 1	Magobing	Residence	Magobing Block A H/N 81A	Soil	13.04.05			NAD	RU	1997
M-MD 81a - 2	Magobing	Residence	Magobing Block A H/N 81A	Soil	13.04.05			NAD	RU	1997
M-MD 81a - 3	Magobing	Residence	Magobing Block A H/N 81A	Soil	13.04.05			NAD	RU	1997
M-MD 81a - 4	Magobing	Residence	Magobing Block A H/N 81A	Soil	13.04.05			NAD	RU	1997
M-MD 81a - 5	Magobing	Residence	Magobing Block A H/N 81A	Block	13.04.05	Poor	no	1-3% crocid	RU	1997
MNM 53a -1	Magobing	Residence	Magobing Block A H/N 53	Soil	13.04.05			Trace	RU	1989
MNM 53a -2	Magobing	Residence	Magobing Block A H/N 53	Soil	13.04.05			Trace	RU	1989
MNM 53a -3	Magobing	Residence	Magobing Block A H/N 53	Soil	13.04.05			NAD	RU	1989
MNM 53a -4	Magobing	Residence	Magobing Block A H/N 53	Soil	13.04.05			Trace	RU	1989
MNM 53a -5	Magobing	Residence	Magobing Block A H/N 53	Block	13.04.05	-	no	20-30% crocid	RU	1989
MNM 53a -6	Magobing	Residence	Magobing Block A H/N 53	Foundation	13.04.05	-	yes	5-10% crocid	RU	1989
M-BP 5a - 1	Magobing	Residence	Magobing Block A H/N 5A	Soil	13.04.05			Trace	RU	1978
M-BP 5a - 2	Magobing	Residence	Magobing Block A H/N 5A	Soil	13.04.05			NAD	RU	1978
M-BP 5a - 3	Magobing	Residence	Magobing Block A H/N 5A	Soil	13.04.05			Trace	RU	1978
M-BP 5a - 4	Magobing	Residence	Magobing Block A H/N 5A	Block	13.04.05	Fair	no	10-20%	RU	1978

M-BP 5a - 5	Magobing	Residence	Magobing Block A H/N 5A	Soil	13.04.04			NAD	RU	1978
MJM40-1	Magojaneng	Residence	House No 40E (next to)	Soil	22.04.05			NAD	RU	2002
MJM40-2	Magojaneng	Residence	House No 40E (next to)	Soil	22.04.05			NAD	RU	2002
MJM40-3	Magojaneng	Residence	House No 40E (next to)	Soil	22.04.05			Trace	RU	2002
MJM40-4	Magojaneng	Residence	House No 40E (next to)	Soil	22.04.05			NAD	RU	2002
MJM40-5	Magojaneng	Residence	House No 40E (next to)	Block	22.04.05	no		3-5% crocid	RU	2002
MJM40-6	Magojaneng	Residence	House No 40E (next to)	Foundation slab material	22.04.05			NAD	RU	2002
MMM40-1	Magojaneng	Residence	House No 40E	Soil	22.04.05			NAD	RU	1969
MMM40-2	Magojaneng	Residence	House No 40E	Soil	22.04.05			NAD	RU	1969
MMM40-3	Magojaneng	Residence	House No 40E	Soil	22.04.05			NAD	RU	1969
MMM40-4	Magojaneng	Residence	House No 40E	Soil	22.04.05			NAD	RU	1969
MMM40-5	Magojaneng	Residence	House No 40E	Floor	22.04.05			3-5% crocid	RU	1969
MJL57-1	Magojaneng	Residence	House No 57E	Soil	22.04.05			Trace	RU	1969
MJL57-2	Magojaneng	Residence	House No 57E	Soil	22.04.05			NAD	RU	1969
MJL57-3	Magojaneng	Residence	House No 57E	Soil	22.04.05			Trace	RU	1969
MJL57-4	Magojaneng	Residence	House No 57E	Soil	22.04.05			NAD	RU	1969
MJL57-5	Magojaneng	Residence	House No 57E	Block	22.04.05		no	1-3% crocid	RU	1969
MJL57-6	Magojaneng	Residence	House No 57E	Foundation slab material	22.04.05		yes	1-3% crocid	RU	1969
MJK35-1	Magojaneng	Residence	House No E35	Soil	22.04.05	no		NAD	RU	2001
MJK35-2	Magojaneng	Residence	House No E35	Soil	22.04.05	no		Trace	RU	2001
MJK35-3	Magojaneng	Residence	House No E35	Soil	22.04.05			NAD	RU	2001
MJK35-4	Magojaneng	Residence	House No E35	Soil	22.04.05			NAD	RU	2001
MJK35-5	Magojaneng	Residence	House No E35	Block	22.04.05		no	3-5% crocid	RU	2001
MJK35-6	Magojaneng	Residence	House No E35	Foundation slab material	22.04.05	no		NAD	RU	2001
MJK35-7	Magojaneng	Residence	House No E35	Roof	22.04.05	yes	no	>50% crocid & chrys	RU	2001
MPT29-1	Magojaneng	Residence	House No E29	Soil	22.04.05			NAD	RU	1999
MPT29-2	Magojaneng	Residence	House No E29	Soil	22.04.05			NAD	RU	1999
MPT29-3	Magojaneng	Residence	House No E29	Soil	22.04.05			NAD	RU	1999
MPT29-4	Magojaneng	Residence	House No E29	Soil	22.04.05			NAD	RU	1999
MPT29-5	Magojaneng	Residence	House No E29	Block	22.04.05		no	3-5% crocid	RU	1999
MAO-1	Magojaneng	Residence	House No 121	Soil	22.04.05			Trace	RU	2000
MAO-2	Magojaneng	Residence	House No 121	Soil	22.04.05			Trace	RU	2000
MAO-3	Magojaneng	Residence	House No 121	Soil	22.04.05			Trace	RU	2000
MAO-4	Magojaneng	Residence	House No 121	Soil	22.04.05			Trace	RU	2000
MAO-5	Magojaneng	Residence	House No 121	Block	22.04.05		no	3-5% crocid	RU	2000
MJP-1	Magojaneng	Residence	House No E24	Soil	19.04.05	no		Trace	RU	1989
MJP-2	Magojaneng	Residence	House No E24	Soil	19.04.05	yes		Trace	RU	1989

MJP-3	Magojaneng	Residence	House No E24	Soil	19.04.05				NAD	RU	1989
MJP-4	Magojaneng	Residence	House No E24	Soil	19.04.05	yes			Trace	RU	1989
MJP-5	Magojaneng	Residence	House No E24	Block	19.04.05	yes			1-3% crocid	RU	1989
MJP-6	Magojaneng	Residence	House No E24	Foundation slab material	19.04.05	yes			3-5% crocid	RU	1989
M-FMC-1	Magojaneng	Church	Five Morningstar Church	Soil	19.04.05				Trace	RU	2000
M-FMC-2	Magojaneng	Church	Five Morningstar Church	Soil	19.04.05				Trace	RU	2000
M-FMC-3	Magojaneng	Church	Five Morningstar Church	Soil	19.04.05				Trace	RU	2000
M-FMC-4	Magojaneng	Church	Five Morningstar Church	Soil	19.04.05				NAD	RU	2000
M-FMC-5	Magojaneng	Church	Five Morningstar Church	Block	19.04.05		Poor		10-20% crocid	RU	2000
M-MM34E-1	Magojaneng	Residential	Magojaneng Village H/N 34E	Soil	19.04.05				NAD	RU	1999
M-MM34E-2	Magojaneng	Residential	Magojaneng Village H/N 34E	Soil	19.04.05				NAD	RU	1999
M-MM34E-3	Magojaneng	Residential	Magojaneng Village H/N 34E	Soil	19.04.05				NAD	RU	1999
M-MM34E-4	Magojaneng	Residential	Magojaneng Village H/N 34E	Soil	19.04.05				NAD	RU	1999
M-MM34E-5	Magojaneng	Residential	Magojaneng Village H/N 34E	Soil	19.04.05				Trace	RU	1999
M-ACS - 1	Magojaneng	Residential	Akanyang Combines S	Soil	19.04.05				Trace	RU	1980
M-ACS - 2	Magojaneng	Residential	Akanyang Combines S	Soil	19.04.05				NAD	RU	1980
M-ACS - 3	Magojaneng	Residential	Akanyang Combines S	Soil	19.04.05				NAD	RU	1980
M-ACS - 4	Magojaneng	Residential	Akanyang Combines S	Soil	19.04.05				Trace	RU	1980
M-ACS - 5	Magojaneng	Residential	Akanyang Combines S	Soil	19.04.05				NAD	RU	1980
M-JR 43e - 1	Magojaneng	Residence	Magojaneng H/N 43E	Soil	22.04.05				Trace	RU	1996
M-JR 43e - 2	Magojaneng	Residence	Magojaneng H/N 43E	Soil	22.04.05				NAD	RU	1996
M-JR 43e - 3	Magojaneng	Residence	Magojaneng H/N 43E	Soil	22.04.05				NAD	RU	1996
M-JR 43e - 4	Magojaneng	Residence	Magojaneng H/N 43E	Soil	22.04.05			yes	>50%	RU	1996
M-MJ 32e - 1	Magojaneng	Residence	Magojaneng Block E H/N 32	Soil	22.04.05				NAD	RU	1990
M-MJ 32e - 2	Magojaneng	Residence	Magojaneng Block E H/N 32	Soil	22.04.05				NAD	RU	1990
M-MJ 32e - 3	Magojaneng	Residence	Magojaneng Block E H/N 32	Soil	22.04.05				NAD	RU	1990
M-MJ 32e - 4	Magojaneng	Residence	Magojaneng Block E H/N 32	Soil	22.04.05				NAD	RU	1990
M-MJ 32e - 5	Magojaneng	Residence	Magojaneng Block E H/N 32	Block	22.04.05		Poor	yes	3-5% crocid	RU	1990
M-MJ 32e - 6	Magojaneng	Residence	Magojaneng Block E H/N 32	Foundation	22.04.05		Poor		NAD	RU	1990
MMB103e - 1	Magojaneng	Residence	Mogojaneng Village H/N 103e	Soil	22.04.05				Trace	RU	1980
MMB103e - 2	Magojaneng	Residence	Mogojaneng Village H/N 103e	Soil	22.04.05				Trace	RU	1980
MMB103e - 3	Magojaneng	Residence	Mogojaneng Village H/N 103e	Soil	22.04.05				Trace	RU	1980
MMB103e - 4	Magojaneng	Residence	Mogojaneng Village H/N 103e	Soil	22.04.05				Trace	RU	1980
MMB103e - 5	Magojaneng	Residence	Mogojaneng Village H/N 103e	Block	22.04.05		Poor	no	10-20% crocid	RU	1980
MWM 48e - 1	Magojaneng	Residence	Magojaneng Block H/N 48	Soil	19.04.05				Trace	RU	1968
MWM 48e - 2	Magojaneng	Residence	Magojaneng Block H/N 48	Soil	19.04.05				Trace	RU	1968
MWM 48e - 3	Magojaneng	Residence	Magojaneng Block H/N 48	Soil	19.04.05				Trace	RU	1968
MWM 48e - 4	Magojaneng	Residence	Magojaneng Block H/N 48	Soil	19.04.05				Trace	RU	1968

MWM 48e - 5	Magojaneng	Residence	Magojaneng Block H/N 48	Floor	19.04.05	Poor	no	5-10% crocid	RU	1968
M-WC - 1	Magojaneng	Church	Magojaneng Wessel Church	Soil	19.04.05			NAD	RU	1998
M-WC - 2	Magojaneng	Church	Magojaneng Wessel Church	Soil	19.04.05			Trace	RU	1998
M-WC - 3	Magojaneng	Church	Magojaneng Wessel Church	Soil	19.04.05			NAD	RU	1998
M-WC - 4	Magojaneng	Church	Magojaneng Wessel Church	Soil	19.04.05			Trace	RU	1998
M-WC - 5	Magojaneng	Church	Magojaneng Wessel Church	Block	19.04.05	Fair	no	10-20% crocid	RU	1998
MTP 66e - 1	Magojaneng	Residence	Magojaneng Block E H/N 66	Soil	19.04.05			NAD	RU	1978
MTP 66e - 2	Magojaneng	Residence	Magojaneng Block E H/N 66	Soil	19.04.05			Trace	RU	1978
MTP 66e - 3	Magojaneng	Residence	Magojaneng Block E H/N 66	Soil	19.04.05			NAD	RU	1978
MTP 66e - 4	Magojaneng	Residence	Magojaneng Block E H/N 66	Soil	19.04.05			NAD	RU	1978
MTP 66e - 5	Magojaneng	Residence	Magojaneng Block E H/N 66	Block	19.04.05	Poor	no	1-3% crocid	RU	1978
M-BT 44e - 1	Magojaneng	Residence	Magojaneng Block E H/N 44	Soil	19.04.05			NAD	RU	1982
M-BT 44e - 2	Magojaneng	Residence	Magojaneng Block E H/N 44	Soil	19.04.05			Trace	RU	1982
M-BT 44e - 3	Magojaneng	Residence	Magojaneng Block E H/N 44	Soil	19.04.05			NAD	RU	1982
M-BT 44e - 4	Magojaneng	Residence	Magojaneng Block E H/N 44	Soil	19.04.05			NAD	RU	1982
M-BT 44e - 5	Magojaneng	Residence	Magojaneng Block E H/N 44	Foundation	19.04.05	Poor		3-5% crocid	RU	1982
MSO 51e - 1	Magojaneng	Residence	Magojaneng Block E H/N 51	Soil	19.04.05			NAD	RU	1969
MSO 51e - 2	Magojaneng	Residence	Magojaneng Block E H/N 51	Soil	19.04.05			NAD	RU	1969
MSO 51e - 3	Magojaneng	Residence	Magojaneng Block E H/N 51	Soil	19.04.05			NAD	RU	1969
MSO 51e - 4	Magojaneng	Residence	Magojaneng Block E H/N 51	Soil	19.04.05			NAD	RU	1969
MSO 51e - 5	Magojaneng	Residence	Magojaneng Block E H/N 51	Foundation	19.04.05	Fair	no	3-5% crocid	RU	1969
M_GL60a-1	Magojaneng	Residential	Mogobing Block A	Soil	13.04.05			Trace	RU	1974
M_GL60a-2	Magojaneng	Residential	Mogobing Block A	Soil	13.04.05			Trace	RU	1974
M_GL60a-3	Magojaneng	Residential	Mogobing Block A	Soil	13.04.05			Trace	RU	1974
M_GL60a-4	Magojaneng	Residential	Mogobing Block A	Soil	13.04.05			Trace	RU	1974
M_GL60a-5	Magojaneng	Residential	Mogobing Block A	Block	13.04.05	Poor		>50% crocid	RU	1974
M_GL60a-6	Magojaneng	Residential	Mogobing Block A	Foundation	13.04.05	Poor		>50% crocid	RU	1974
MTG-69a-1	Maipeing	Residence	Maipeing Block A H/N 69a	Soil	14.04.05			NAD	RU	1978
MTG-69a-2	Maipeing	Residence	Maipeing Block A H/N 69a	Soil	14.04.05			NAD	RU	1978
MTG-69a-3	Maipeing	Residence	Maipeing Block A H/N 69a	Soil	14.04.05			NAD	RU	1978
MTG-69a-4	Maipeing	Residence	Maipeing Block A H/N 69a	Soil	14.04.05			NAD	RU	1978
MTG-69a-5	Maipeing	Residence	Maipeing Block A H/N 69a	Block	14.04.05	Poor	no	5-10% crocid	RU	1978
M-BM 11d-1	Maipeing	Residence	Maipeing Block D H/N 11d	Soil	14.04.05			Trace	RU	1988
M-BM 11d-2	Maipeing	Residence	Maipeing Block D H/N 11d	Soil	14.04.05			Trace	RU	1988
M-BM 11d-3	Maipeing	Residence	Maipeing Block D H/N 11d	Soil	14.04.05			Trace	RU	1988
M-BM 11d-4	Maipeing	Residence	Maipeing Block D H/N 11d	Soil	14.04.05			Trace	RU	1988
M-BM 11d-5	Maipeing	Residence	Maipeing Block D H/N 11d	Soil	14.04.05		no	5-10% crocid	RU	1988
M-BM 11d-6	Maipeing	Residence	Maipeing Block D H/N 11d	Block	14.04.05	Poor	yes	5-10% crocid	RU	1988

MPOH - 1	Maipeing	Residence	Maipeing (Open House)	Soil	14.04.05			Trace	RU	-
MPOH - 2	Maipeing	Residence	Maipeing (Open House)	Soil	14.04.05			Trace	RU	-
MPOH - 3	Maipeing	Residence	Maipeing (Open House)	Soil	14.04.05			NAD	RU	-
MPOH - 4	Maipeing	Residence	Maipeing (Open House)	Soil	14.04.05			NAD	RU	-
MPOH - 5	Maipeing	Residence	Maipeing (Open House)	Block	14.04.05	Poor	no	5-10% crocid	RU	-
MNS159a-1	Maipeing	Residence	Maipeing Block A H/N 159a	Soil	15.04.04			NAD	RU	1980
MNS159a-2	Maipeing	Residence	Maipeing Block A H/N 159a	Soil	15.04.04			NAD	RU	1980
MNS159a-3	Maipeing	Residence	Maipeing Block A H/N 159a	Soil	15.04.04			NAD	RU	1980
MNS159a-4	Maipeing	Residence	Maipeing Block A H/N 159a	Soil	15.04.04			NAD	RU	1980
MNS159a-5	Maipeing	Residence	Maipeing Block A H/N 159a	Block	15.04.04	Poor	no	5-10% crocid	RU	1980
MRD No113a-1	Maipeing	Residence	Maipeing Block A H/N 113a	Soil	15.04.05			NAD	RU	1981
MRD No113a-2	Maipeing	Residence	Maipeing Block A H/N 113a	Soil	15.04.05			Trace	RU	1981
MRD No113a-3	Maipeing	Residence	Maipeing Block A H/N 113a	Soil	15.04.05			NAD	RU	1981
MRD No113a-4	Maipeing	Residence	Maipeing Block A H/N 113a	Soil	15.04.05			NAD	RU	1981
MRD No113a-5	Maipeing	Residence	Maipeing Block A H/N 113a	Foundation	15.04.05	Fair		NAD	RU	1981
MRD No113a-6	Maipeing	Residence	Maipeing Block A H/N 113a	Block	15.04.05	Fair		NAD	RU	1981
M-DD 265c-1	Maipeing	Residence	Maipeing Block C H/N 265c	Foundation	15.04.05	Poor		3-5% crocid	RU	2004
M-KT No104a-1	Maipeing	Residence	Maipeing Block A H/N 104a	Soil	15.04.05			NAD	RU	1981
M-KT No104a-2	Maipeing	Residence	Maipeing Block A H/N 104a	Soil	15.04.05			NAD	RU	1981
M-KT No104a-3	Maipeing	Residence	Maipeing Block A H/N 104a	Soil	15.04.05			NAD	RU	1981
M-KT No104a-4	Maipeing	Residence	Maipeing Block A H/N 104a	Soil	15.04.05			NAD	RU	1981
M-KT No104a-5	Maipeing	Residence	Maipeing Block A H/N 104a	Foundation	15.04.05			Trace	RU	1981
M-KT No104a-6	Maipeing	Residence	Maipeing Block A H/N 104a	Block	15.04.05			3-5% crocid	RU	1981
M-PS - 1	Maipeing	School	Maipeing Primary School	Soil	15.04.05			NAD	RU	1985
M-PS - 2	Maipeing	School	Maipeing Primary School	Soil	15.04.05			NAD	RU	1985
M-PS - 3	Maipeing	School	Maipeing Primary School	Soil	15.04.05			5-10% crocid	RU	1985
M-PS - 4	Maipeing	School	Maipeing Primary School	Soil	15.04.05			NAD	RU	1985

M-PS - 5	Maipeing	School	Maipeing Primary School	Quat.Block	15.04.05		Fair		5-10% crocid	RU	1985
M-PS - 6	Maipeing	School	Maipeing Primary School	Sch.Block	15.04.05		Fair		NAD	RU	1985
MPS 178 - 1	Maipeing	Residence	Maipeing Block C H/N 178	Soil	15.04.04				1-3% crocid	RU	2000
MPS 178 - 2	Maipeing	Residence	Maipeing Block C H/N 178	Soil	15.04.04				Trace	RU	2000
MPS 178 - 3	Maipeing	Residence	Maipeing Block C H/N 178	Soil	15.04.04				1-3% crocid	RU	2000
MPS 178 - 4	Maipeing	Residence	Maipeing Block C H/N 178	Soil	15.04.04				Trace	RU	2000
MPS 178 - 5	Maipeing	Residence	Maipeing Block C H/N 178	Block	15.04.04		Poor	no	10-20% crocid	RU	2000
MGJ 89b - 1	Maipeing	Residence	Maipeing Block B H/N 89b	Block	20.04.05		Fair	yes	5-10% crocid	RU	1997
MGJ 89b - 2	Maipeing	Residence	Maipeing Block B H/N 89b	Ceiling	20.04.05		Fair	no	>50% Crocid & Chry	RU	1997
MUCC - 1	Maipeing	Residence	Maipeing Village	Soil	20.04.05				Trace	RU	1997
MUCC - 2	Maipeing	Residence	Maipeing Village	Soil	20.04.05				NAD	RU	1997
MUCC - 3	Maipeing	Residence	Maipeing Village	Soil	20.04.05				1-3% crocid	RU	1997
MUCC - 4	Maipeing	Residence	Maipeing Village	Soil	20.04.05				Trace	RU	1997
MUCC - 5	Maipeing	Residence	Maipeing Village	Foundation	20.04.05		Poor	yes	3-5% crocid	RU	1997
M-MM 73d - 1	Maipeing	Residence	Maipeing Block D H/N 73d	Soil	20.04.05				NAD	RU	1973
M-MM 73d - 2	Maipeing	Residence	Maipeing Block D H/N 73d	Soil	20.04.05				Trace	RU	1973
M-MM 73d - 3	Maipeing	Residence	Maipeing Block D H/N 73d	Soil	20.04.05				Trace	RU	1973
M-MM 73d - 4	Maipeing	Residence	Maipeing Block D H/N 73d	Soil	20.04.05				Trace	RU	1973
M-AC 150 - 1	Maipeing	Church	Maipeing Anglican Church	Soil	20.04.05				NAD	RU	1960
M-AC 150 - 2	Maipeing	Church	Maipeing Anglican Church	Soil	20.04.05				NAD	RU	1960
M-AC 150 - 3	Maipeing	Church	Maipeing Anglican Church	Soil	20.04.05				NAD	RU	1960
M-AC 150 - 4	Maipeing	Church	Maipeing Anglican Church	Soil	20.04.05				NAD	RU	1960
MKG30-1	Maipeng	Residence	Maipeng Block	Soil	14.04.05	no			NAD	RU	1988
MKG30-2	Maipeng	Residence	Maipeng Block	Soil	14.04.05	no			Trace	RU	1988
MKG30-3	Maipeng	Residence	Maipeng Block	Soil	14.04.05	no			NAD	RU	1988
MKG30-4	Maipeng	Residence	Maipeng Block	Soil	14.04.05	no			NAD	RU	1988
MKG30-5	Maipeng	Residence	Maipeng Block	Block	14.04.05	yes			1-3% crocid	RU	1988
MKG30-6	Maipeng	Residence	Maipeng Block	Foundation slab material	14.04.05	no					1988
B1	Maruping	Residence	Maropeng Village	Soil	16.10.03		Poor	yes	1-3% crocid	Omni	
B2	Maruping	Residence	Maropeng Village	Soil	16.10.03		Poor	yes	1-3% crocid	Omni	
MV-1C	Maruping	Residence	Maropeng Village	Soil	16.10.03		Poor	yes	1-3% crocid	Omni	
B3	Maruping	Residence	Maropeng Village	Plaster	16.10.03		Poor	yes	3-5% crocid	Omni	
B4	Maruping	Residence	Maropeng Village	Plaster	16.10.03		Poor	yes	3-5% crocid	Omni	
MV-2C	Maruping	Residence	Maropeng Village	Plaster	16.10.03		Poor	yes	3-5% crocid	Omni	
MRP-KN2	Maruping	Residence	M/Martishi House No 736	Soil	01.12.04	no			Trace	RU	1992
MRP-KN4	Maruping	Residence	M/Martishi House No 736	Foundation slab material	01.12.04	no			NAD	RU	1992
MRP-CL1	Maruping	Residence	Sekuwenu House No A65	Soil	01.12.04	no			Trace	RU	1965

MRP-CL2	Maruping	Residence	Sekuwenu House No A65	Soil	01.12.04	no	Trace	RU	1965
MRP-CL5	Maruping	Residence	Sekuwenu House No A65	Plaster	01.12.04	no	NAD	RU	1965
MRP-CL6	Maruping	Residence	Sekuwenu House No A65	Bricks	01.12.04	no	NAD	RU	1965
MRP-TL1	Maruping	Residence	Sekuwenu House No 66	Soil	01.12.04	no	NAD	RU	1965
MRP-TL2	Maruping	Residence	Sekuwenu House No 66	Soil	01.12.04	no	Trace	RU	1965
MRP-TL3	Maruping	Residence	Sekuwenu House No 66	Soil	01.12.04	no	Trace	RU	1965
MRP-TL4	Maruping	Residence	Sekuwenu House No 66	Foundation slab material	01.12.04	no	NAD	RU	1965
MRP-AT2	Maruping	Residence	Setlhakeng House No E1033	Foundation slab material	30.11.04	no	Trace	RU	
MRP-AT3	Maruping	Residence	Setlhakeng House No E1033	Soil	30.11.04	no	Trace	RU	
MRP-AT5	Maruping	Residence	Setlhakeng House No E1033	Foundation slab material	30.11.04	no	NAD	RU	
MRP-BO1	Maruping	Residence	Tsago House No E1044	Soil	30.11.04	no	NAD	RU	1965
MRP-BO2	Maruping	Residence	Tsago House No E1044	Soil	30.11.04	no	NAD	RU	1965
MRP-BO3	Maruping	Residence	Tsago House No E1044	Soil	30.11.04	no	Trace	RU	1965
MRP-BO4	Maruping	Residence	Tsago House No E1044	Foundation slab material	30.11.04	no	NAD	RU	1965
MRP-UM1	Maruping	School	Gamohana Middle School	Soil	01.12.04	no	Trace	RU	1981
MRP-UM2	Maruping	School	Gamohana Middle School	Soil	01.12.04	no	NAD	RU	1981
MRP-UM3	Maruping	School	Gamohana Middle School	Soil	01.12.04	no	NAD	RU	1981
MRP-UM4	Maruping	School	Gamohana Middle School	Foundation slab material	01.12.04	no	NAD	RU	1981
MRP-UM5	Maruping	School	Gamohana Middle School	Bricks	01.12.04	no	NAD	RU	1981
MRP-UM6	Maruping	School	Gamohana Middle School	Soil	01.12.04	no	NAD	RU	1981
MRP-MM1	Maruping	Residence	Meleke House No 930	Soil	30.12.04	no	NAD	RU	1980
MRP-MM2	Maruping	Residence	Meleke House No 930	Soil	30.12.04	no	NAD	RU	1980
MRP-MM3	Maruping	Residence	Meleke House No 930	Bricks	30.12.04	no	NAD	RU	1980
MRP-MM4	Maruping	Residence	Meleke House No 930	Foundation slab material	30.12.04	no	NAD	RU	1980
MRP-GM1	Maruping	Residence	Tsago House No 1055	Soil	30.12.04	no	NAD	RU	1970
MRP-GM2	Maruping	Residence	Tsago House No 1055	Soil	30.12.04	no	NAD	RU	1970
MRP-GM3	Maruping	Residence	Tsago House No 1055	Soil	30.12.04	no	NAD	RU	1970
MRP-GM4	Maruping	Residence	Tsago House No 1055	Soil	30.12.04	no	NAD	RU	1970
MRP-MLA1	Maruping	Residence	Meleke House No 961	Soil	30.11.04	no	Trace	RU	1970
MRP-MLA2	Maruping	Residence	Meleke House No 961	Soil	30.11.04	no	NAD	RU	1970
MRP-MLA3	Maruping	Residence	Meleke House No 961	Bricks	30.11.04	no	NAD	RU	1970
MRP-MLA4	Maruping	Residence	Meleke House No 961	Foundation slab material	30.11.04	no	NAD	RU	1970
MRP-MP1	Maruping	School	Maruping Primary School	Soil	30.11.04	no	NAD	RU	1926
MRP-MP2	Maruping	School	Maruping Primary School	Soil	30.11.04	no	NAD	RU	1926
MRP-MP4	Maruping	School	Maruping Primary School	Bricks	30.11.04	no	NAD	RU	1926
MRP-MP5	Maruping	School	Maruping Primary School	Soil	30.11.04	no	NAD	RU	1926
MRP-MP6	Maruping	School	Maruping Primary School	Soil	30.11.04	no	NAD	RU	1926
MRP-MP7	Maruping	School	Maruping Primary School	Soil	30.11.04	no	NAD	RU	1926

MRP-DM1	Maruping	Residence	Matlapeng House No E294	Soil	02.12.04	no		Trace	RU	1955
MRP-DM2	Maruping	Residence	Matlapeng House No E294	Plaster	02.12.04	no		Trace	RU	1955
MRP-DM3	Maruping	Residence	Matlapeng House No E294	Soil	02.12.04	no		Trace	RU	1955
MRP-DM4	Maruping	Residence	Matlapeng House No E294	Bricks	02.12.04	no		NAD	RU	1955
MRP-SP1	Maruping	School	Seupe Primary School	Soil	02.12.04	no		NAD	RU	1992
MRP-SP2	Maruping	School	Seupe Primary School	Soil	02.12.04	no		NAD	RU	1992
MRP-SP3	Maruping	School	Seupe Primary School	Soil	02.12.04	no		NAD	RU	1992
MRP-SP4	Maruping	School	Seupe Primary School	Soil	02.12.04	no		NAD	RU	1992
MRP-SP5	Maruping	School	Seupe Primary School	Bricks	02.12.04	no		NAD	RU	1992
MRP-SP6	Maruping	School	Seupe Primary School	Soil	02.12.04	no		NAD	RU	1992
MRP-SP7	Maruping	School	Seupe Primary School	Foundation slab material	02.12.04	no		NAD	RU	1992
MRP-DS1	Maruping	Residence	Matlapeng House No 314	Soil	02.12.04	no		NAD	RU	1978
MRP-DS2	Maruping	Residence	Matlapeng House No 314	Soil	02.12.04	no		NAD	RU	1978
MRP-DS3	Maruping	Residence	Matlapeng House No 314	Foundation slab material	02.12.04	no		NAD	RU	1978
MRP-DS4	Maruping	Residence	Matlapeng House No 314	Bricks	02.12.04	no		NAD	RU	1978
MRP-OC1	Maruping	Private business	Oabona Café/House No E267	Soil	02.12.04	no		NAD	RU	1982
MRP-OC2	Maruping	Private business	Oabona Café/House No E267	Soil	02.12.04	no		Trace	RU	1982
MRP-OC3	Maruping	Private business	Oabona Café/House No E267	Bricks	02.12.04	no		NAD	RU	1982
MRP-OC4	Maruping	Private business	Oabona Café/House No E267	Foundation slab material	02.12.04	no		NAD	RU	1982
MRP-OC5	Maruping	Private business	Oabona Café/House No E267	Soil	02.12.04	no		NAD	RU	1982
MRP-MPA1	Maruping	Residence	Longameng House No E128	Soil	07.12.04	no		Trace	RU	1994
MRP-MPA2	Maruping	Residence	Longameng House No E128	Foundation slab material	07.12.04	no		NAD	RU	1994
MRP-MPA3	Maruping	Residence	Longameng House No E128	Plaster	07.12.04	no	no	Trace	RU	1994
MRP-MPA4	Maruping	Residence	Longameng House No E128	Bricks	07.12.04	no		NAD	RU	1994
MRP-ZKT1	Maruping	Residence	House No E161	Soil	07.12.04	no		Trace	RU	1980
MRP-ZKT2	Maruping	Residence	House No E161	Soil	07.12.04	no		NAD	RU	1980
MRP-JC1	Maruping	Residence	House No E102	Soil	07.12.04	no		NAD	RU	1980
MRP-JC2	Maruping	Residence	House No E102	Bricks	07.12.04	no		NAD	RU	1980
MRP-GG1	Maruping	Residence	House No E164	Soil	07.12.04	no		1-3% crocid	RU	1968
MRP-GG2	Maruping	Residence	House No E164	Soil	07.12.04	no		Trace	RU	1968
MRP-IM1	Maruping	Residence	House No E157	Soil	07.12.04	no		NAD	RU	1981
MRP-IM2	Maruping	Residence	House No E157	Soil	07.12.04	no		NAD	RU	1981
MRP-IM3	Maruping	Residence	House No E157	Soil	07.12.04	no		NAD	RU	1981
MRP-IM4	Maruping	Residence	House No E157	Plaster	07.12.04	no		NAD	RU	1981
MRP-SM1	Maruping	Residence	House No E698	Soil	01.12.04	no		NAD	RU	1989
MRP-SM2	Maruping	Residence	House No E698	Soil	01.12.04	no		Trace	RU	1989
MRP-SM3	Maruping	Residence	House No E698	Soil	01.12.04	no		NAD	RU	1989
MRP-SM4	Maruping	Residence	House No E698	Bricks	01.12.04	no		NAD	RU	1989

MRP-MC1	Maruping	Hospital/Clinic	Maruping Clinic	Soil	02.12.04	no		NAD	RU	1998
MRP-MC2	Maruping	Hospital/Clinic	Maruping Clinic	Soil	02.12.04	no		NAD	RU	1998
MRP-MC3	Maruping	Hospital/Clinic	Maruping Clinic	Soil	02.12.04	no		NAD	RU	1998
MRP-MC4	Maruping	Hospital/Clinic	Maruping Clinic	Soil	02.12.04	no		NAD	RU	1998
MRP-KN1	Maruping	Residence	M/Martishi House No 736	Soil	01.12.04	yes		Trace	RU	1992
MRP-KN3	Maruping	Residence	M/Martishi House No 736	Bricks	01.12.04	yes	no	3-5% crocid	RU	1992
MRP-CL3	Maruping	Residence	Sekuwenu House No A65	Soil	01.12.04	yes		1-3% crocid	RU	1965
MRP-CL4	Maruping	Residence	Sekuwenu House No A65	Soil	01.12.04	yes		1-3% crocid	RU	1965
MRP-ML1	Maruping	Residence	Tsago-next House No E1055	Soil	30.12.04	yes		1-3% crocid	RU	
MRP-ML2	Maruping	Residence	Tsago-next House No E1055	Soil	30.12.04	yes		1-3% crocid	RU	
MRP-AT1	Maruping	Residence	Setlhakeng House No E1033	Soil	30.11.04	yes		NAD	RU	
MRP-AT4	Maruping	Residence	Setlhakeng House No E1033	Bricks	30.11.04	yes		Trace	RU	
MRP-AT6	Maruping	Residence	Setlhakeng House No E1033	Soil	30.11.04	yes		1-3% crocid	RU	
MRP-MP3	Maruping	School	Maruping Primary School	Foundation slab material	30.11.04	yes	no	Trace	RU	1926
MRP-ZKT3	Maruping	Residence	House No E161	Bricks	07.12.04	yes	no	3-5% crocid	RU	1980
MRP-ZKT4	Maruping	Residence	House No E161	Foundation slab material	07.12.04	yes	yes	10-20% crocid	RU	1980
MRP-GG3	Maruping	Residence	House No E164	Soil	07.12.04	yes		NAD	RU	1968
MRP-GG5	Maruping	Residence	House No E164	Bricks	07.12.04	yes	yes	3-5% crocid	RU	1968
MRP-GG4	Maruping	Residence	House No E164	Foundation slab material	07.12.04			NAD	RU	1968
MS-AL1	Masonkong	Residence	House No 70E	Soil	07.12.04	no		Trace	RU	1976
MS-AL2	Masonkong	Residence	House No 70E	Soil	07.12.04	no		Trace	Omni	1976
MS-AL3	Masonkong	Residence	House No 70E	Soil	07.12.04	no		Trace	RU	1976
MS-AL6	Masonkong	Residence	House No 70E	Plaster	07.12.04	no		NAD	RU	1976
MS-ES1	Masonkong	Residence	House No E15	Soil	07.12.04	no		Trace	RU	1999
MS-ES2	Masonkong	Residence	House No E15	Soil	07.12.04	no		NAD	RU	1999
MS-ES3	Masonkong	Residence	House No E15	Soil	07.12.04	no		NAD	RU	1999
MS-ES4	Masonkong	Residence	House No E15	Soil	07.12.04	no				1999
MS-JT1	Masonkong	Residence	House No 33	Fiberglass	07.11.04	no		NAD	RU	
MS-JM2	Masonkong	Residence	House No 114	Soil	09.12.04	no		NAD	RU	1997
MS-JM3	Masonkong	Residence	House No 114	Soil	09.12.04	no		NAD	RU	1997
MS-JM4	Masonkong	Residence	House No 114	Soil	09.12.04	no				1997
MS-JL1	Masonkong	Residence	House No 2E	Soil	07.12.04	no		NAD	RU	1995
MS-JL2	Masonkong	Residence	House No 2E	Soil	07.12.04	no		NAD	RU	1995
MS-JL3	Masonkong	Residence	House No 2E	Soil	07.12.04	no		NAD	RU	1995
MS-JL4	Masonkong	Residence	House No 2E	Soil	07.12.04	no		NAD	RU	1995
MS-JLA1	Masonkong	Residence	House No 101	Soil	08.12.04	no		Trace	RU	
MS-JLA2	Masonkong	Residence	House No 101	Soil	08.12.04	no		Trace	RU	
MS-JLA3	Masonkong	Residence	House No 101	Soil	08.12.04	no		NAD	RU	

MS-JLA4	Masonkong	Residence	House No 101		Soil	08.12.04	no		Trace	RU	
MS-OL1	Masonkong	Residence	House No 71		Soil	07.12.04	no		Trace	Omni	1997
MS-OL2	Masonkong	Residence	House No 71		Soil	07.12.04	no		NAD	RU	1997
MS-OL3	Masonkong	Residence	House No 71		Soil	07.12.04	no		NAD	RU	1997
MS-OL4	Masonkong	Residence	House No 71		Soil	07.12.04	no		NAD	RU	1997
MS-GL2	Masonkong	Residence	Lakhobe Residence		Soil	08.12.04	no		NAD	RU	1978
MS-GL3	Masonkong	Residence	Lakhobe Residence		Soil	08.12.04	no		Trace	RU	1978
MS-GL4	Masonkong	Residence	Lakhobe Residence		Soil	08.12.04	no		NAD	RU	1978
MS-GL5	Masonkong	Residence	Lakhobe Residence		Foundation slab material	08.12.04	no		NAD	RU	1978
MS-GL6	Masonkong	Residence	Lakhobe Residence		Block	08.12.04	no	no	10-20% crocid	RU	1978
MS-CR1	Masonkong	Road	Masankong Road		Soil	09.12.04	no		NAD	RU	
MS-AL4	Masonkong	Residence	House No 70E		Soil	07.12.04	yes		NAD	RU	1976
MS-AL5	Masonkong	Residence	House No 70E		Soil	07.12.04	yes		10-20% crocid	RU	1976
MS-AL7	Masonkong	Residence	House No 70E		Foundation slab material	07.12.04	yes	yes	5-10% crocid	RU	1976
MS-AL8	Masonkong	Residence	House No 70E		Block	07.12.04	yes	no	5-10% crocid	RU	1976
MS-ES5	Masonkong	Residence	House No E15		Block	07.12.04	yes	no	3-5% crocid	RU	1999
MS-WM1	Masonkong	Residence	House No 1		Soil	08.12.04	yes		Trace	RU	2003
MS-WM2	Masonkong	Residence	House No 1		Soil	08.12.04	yes		1-3% crocid	RU	2003
MS-WM3	Masonkong	Residence	House No 1		Soil	08.12.04	yes				2003
MS-WM4	Masonkong	Residence	House No 1		Soil	08.12.04	yes		Trace	RU	2003
MS-WM5	Masonkong	Residence	House No 1		Foundation slab material	08.12.04	yes	no	30-40% crocid	RU	2003
MS-WM6	Masonkong	Residence	House No 1		Block	08.12.04	yes	no	10-20% crocid	RU	2003
MS-MM1	Masonkong	Residence	House No 13		Roof	09.12.04	yes	no	>50% Crocid & Chrys	RU	1997
MS-JM1	Masonkong	Residence	House No 114		Soil	09.12.04	yes		NAD		1997
MS-JM5	Masonkong	Residence	House No 114		Roof	09.12.04	yes	no	>50% Crocid & Chrys	RU	1997
MS-JL5	Masonkong	Residence	House No 2E		Block	07.12.04	yes	no	5-10% crocid	RU	1995
MS-JLA5	Masonkong	Residence	House No 101		Soil	08.12.04	yes	no	5-10% crocid	RU	
MS-OL5	Masonkong	Residence	House No 71		Ceiling	07.12.04	yes	no	>50% Crocid & Chrys	RU	1997
MS-GL1	Masonkong	Residence	Lakhobe Residence		Soil	08.12.04	yes				1978
MS-TT1	Masonkong	Residence	House No 46E		Ceiling	08.12.04	yes		1-5% crocid	RU	1993
MS-TT2	Masonkong	Residence	House No 46E		Roof	08.12.04	yes	yes	70-80% crocid	RU	1993
IMS-1	Mothibistad	School	Iketleletso Middle School	I.M.S	Soil	19.04.05			NAD	RU	1978
IMS-2	Mothibistad	School	Iketleletso Middle School	I.M.S	Soil	19.04.05			NAD	RU	1978
IMS-3	Mothibistad	School	Iketleletso Middle School	I.M.S	Soil	19.04.05			NAD	RU	1978
IMS-4	Mothibistad	School	Iketleletso Middle School	I.M.S	Soil	19.04.05			NAD	RU	1978
IMS-5	Mothibistad	School	Iketleletso Middle School	I.M.S	Plaster	19.04.05			NAD	RU	1978

LSS - 1	Mothibistad	School	Learamele special school & hostel	Soil	19.04.05		NAD	RU	1990
LSS - 2	Mothibistad	School	Learamele special school & hostel	Soil	19.04.05		NAD	RU	1990
LSS - 3	Mothibistad	School	Learamele special school & hostel	Soil	19.04.05		NAD	RU	1990
LSS - 4	Mothibistad	School	Learamele special school & hostel	Soil	19.04.05		NAD	RU	1990
LSS - 5	Mothibistad	School	Learamele special school & hostel	Soil	19.04.05		NAD	RU	1990
LSS - 6	Mothibistad	School	Learamele special school & hostel	Soil	19.04.05		NAD	RU	1990
MPS -1	Mothibistad	School	Mmabana Pre-School	Soil	19.04.05		NAD	RU	1981
MPS -2	Mothibistad	School	Mmabana Pre-School	Soil	19.04.05		NAD	RU	1981
MPS -3	Mothibistad	School	Mmabana Pre-School	Soil	19.04.05		NAD	RU	1981
MPS -4	Mothibistad	School	Mmabana Pre-School	Soil	19.04.05		NAD	RU	1981
BTHS-1	Mothibistad	School	Batlharo Tlhaping High School & Sports Ground	Soil	19.04.05		NAD	RU	1968
BTHS-2	Mothibistad	School	Batlharo Tlhaping High School & Sports Ground	Soil	19.04.05		NAD	RU	1968
BTHS-3	Mothibistad	School	Batlharo Tlhaping High School & Sports Ground	Soil	19.04.05		NAD	RU	1968
BTHS-4	Mothibistad	School	Batlharo Tlhaping High School & Sports Ground	Foundation	19.04.05	Good	NAD	RU	1968
BTHS-5	Mothibistad	School	Batlharo Tlhaping High School & Sports Ground	Foundation	19.04.05	Good	NAD	RU	1968
BTHS-6	Mothibistad	School	Batlharo Tlhaping High School & Sports Ground	Soil	19.04.05		NAD	RU	1968
BTHS-7	Mothibistad	School	Batlharo Tlhaping High School & Sports Ground	Soil	19.04.05		NAD	RU	1968
BTHS-8	Mothibistad	School	Batlharo Tlhaping High School & Sports Ground	Soil	19.04.05		NAD	RU	1968
BTHS-9	Mothibistad	School	Batlharo Tlhaping High School & Sports Ground	Soil	19.04.05		NAD	RU	1968
BTHS-10	Mothibistad	School	Batlharo Tlhaping High School & Sports Ground	Brick	19.04.05	Good	NAD	RU	1968
MO - 1	Mothibistad	Public Buildings	Magistrate Office M.O	Soil	18.04.05		NAD	RU	1974
MO - 2	Mothibistad	Public Buildings	Magistrate Office M.O	Soil	18.04.05		NAD	RU	1974
MO - 3	Mothibistad	Public Buildings	Magistrate Office M.O	Soil	18.04.05		NAD	RU	1974
MO - 4	Mothibistad	Public Buildings	Magistrate Office M.O	Brick	18.04.05	Good	NAD	RU	1974
PELC-1	Mothibistad	School	Pearly Early Learning Centre	Soil	18.04.05		NAD	RU	1978
PELC-2	Mothibistad	School	Pearly Early Learning Centre	Soil	18.04.05		NAD	RU	1978
SPS -1	Mothibistad	School	Segonyama Primary School & Sports Ground	Soil	18.04.05		NAD	RU	1966
SPS -2	Mothibistad	School	Segonyama Primary School & Sports Ground	Soil	18.04.05		Trace	RU	1966
SPS -3	Mothibistad	School	Segonyama Primary School & Sports Ground	Soil	18.04.05		NAD	RU	1966
SPS -4	Mothibistad	School	Segonyama Primary School & Sports	Brick	18.04.05	Good	NAD	RU	1966

			Ground								
SPS -5	Mothibistad	School	Segonyama Primary School & Sports Ground	Roof	18.04.05		Good	no	>50% Crocidol & Chry	RU	1966
SPS -6	Mothibistad	School	Segonyama Primary School & Sports Ground	Soil	18.04.05				NAD	RU	1966
SPS -7	Mothibistad	School	Segonyama Primary School & Sports Ground	Soil	18.04.05				NAD	RU	1966
MPS-1	Mothibistad	Public Buildings	Mothibistad Police Station	Soil	18.04.05				NAD	RU	1978
MPS-2	Mothibistad	Public Buildings	Mothibistad Police Station	Soil	18.04.05				NAD	RU	1978
MPS-3	Mothibistad	Public Buildings	Mothibistad Police Station	Soil	18.04.05				NAD	RU	1978
MPS-4	Mothibistad	Public Buildings	Mothibistad Police Station	Soil	18.04.05				NAD	RU	1978
TO -1	Mothibistad	Public Buildings	Teba Office	Soil	18.04.05				NAD	RU	1978
TO -2	Mothibistad	Public Buildings	Teba Office	Soil	18.04.05				NAD	RU	1978
SP1	Ncweng	School	Ncweng Primary School	Soil	25.03.04	no	Poor	yes			
S4	Ncweng	School	Ncweng Primary School	Floor dust in classroom	25.03.04	no	Poor	yes	NAD	Omni	
N1	Ncweng	School	New Ncweng Primary School Site	Soil Composite	19.10.04	no	Poor		NAD	RU	
Location	Ncweng	Rehabilitated Dump	Ncweng Village	Edge of rehab slope	19.10.04	no			N/A		
Location	Ncweng	No Sample	Ncweng Village	Houses closest to slope	19.10.04	no			N/A		
GMNPS-1	Ncweng	School	Primary School	Soil	18.11.04	no			NAD	RU	1980
GMNPS-2	Ncweng	School	Primary School	Soil	18.11.04	no			NAD	RU	1980
GMNPS-3	Ncweng	School	Primary School	Soil	18.11.04	no		yes	Trace	Omni	1980
GMNPS-4	Ncweng	School	Primary School	Soil	18.11.04	no			NAD	RU	1980
GMNPS-5	Ncweng	School	Primary School	Soil	18.11.04	no			NAD	RU	1980
C7	Ncweng	School	Ncweng Primary School	Soil	16.10.03	yes	Poor	yes	1-3% crocid	Omni	
C8	Ncweng	School	Ncweng Primary School	Soil	16.10.03	yes	Poor	yes	1-3% crocid	Omni	
S2	Ncweng	School	Ncweng Primary School	Foundation slab material	25.03.04	yes			crocid	Omni	
S3	Ncweng	School	Ncweng Primary School	Dirt under slab	25.03.04	yes	Poor	yes	crocid	Omni	
Location	Ncweng	School	Ncweng Primary School	Soil	19.10.04	yes	Poor		N/A		
GMNPS-6	Ncweng	School	Primary School	Soil	18.11.04	yes			Trace crocid	RU	1980
GMNPS-7	Ncweng	School	Primary School	Foundation slab material	18.11.04	yes			NAD	RU	1980
GMNPS-8	Ncweng	School	Primary School	Building material	18.11.04	yes			Trace	RU	1980
SP2	Ncweng	School	Ncweng Primary School	Soil	25.03.04			yes			
SP3	Ncweng	School	Ncweng Primary School	Soil	25.03.04			yes			
S1	Ncweng	School	Ncweng Primary School	Block exterior	25.03.04				NAD	Omni	
A1A	Ncweng	School	Ncweng Primary School	Soil	25.03.04		Poor	yes	5-10% crocid	Omni	
A1B	Ncweng	School	Ncweng Primary School	Soil	25.03.04		Poor	yes	5-10% crocid	Omni	
A1C	Ncweng	School	Ncweng Primary School	Soil	25.03.04		Poor	yes	5-10% crocid	Omni	
NSP-A1	Ncweng	School	Ncweng Primary School	Soil (composite of A1A-C)	25.03.04		Poor	yes	5-10% crocid	Omni	

A2A	Ncweng	School	Ncweng Primary School	Soil	25.03.04		Poor	yes	1-3% crocid	Omni	
A2B	Ncweng	School	Ncweng Primary School	Soil	25.03.04		Poor	yes	1-3% crocid	Omni	
A2C	Ncweng	School	Ncweng Primary School	Soil	25.03.04		Poor	yes	1-3% crocid	Omni	
NSP-A2	Ncweng	School	Ncweng Primary School	Soil (composite of A2A-C)	25.03.04		Poor	yes	1-3% crocid	Omni	
A3A	Ncweng	School	Ncweng Primary School	Soil	25.03.04		Poor	yes	1-3% crocid	Omni	
A3B	Ncweng	School	Ncweng Primary School	Soil	25.03.04		Poor	yes	1-3% crocid	Omni	
A3C	Ncweng	School	Ncweng Primary School	Soil	25.03.04		Poor	yes	1-3% crocid	Omni	
NSP-A3	Ncweng	School	Ncweng Primary School	Soil (composite of A3A-C)	25.03.04		Poor	yes	1-3% crocid	Omni	
B1A	Ncweng	School	Ncweng Primary School	Soil	25.03.04		Poor	yes	Trace	RU	
B1B	Ncweng	School	Ncweng Primary School	Soil	25.03.04		Poor	yes	Trace	RU	
B1C	Ncweng	School	Ncweng Primary School	Soil	25.03.04		Poor	yes	Trace	RU	
B2A	Ncweng	School	Ncweng Primary School	Soil	25.03.04		Poor	yes	NAD	RU	
B2B	Ncweng	School	Ncweng Primary School	Soil	25.03.04		Poor	yes	Trace	RU	
B2C	Ncweng	School	Ncweng Primary School	Soil	25.03.04		Poor	yes	NAD	RU	
B3A	Ncweng	School	Ncweng Primary School	Soil	25.03.04		Poor	yes	Trace	RU	
B3B	Ncweng	School	Ncweng Primary School	Soil	25.03.04		Poor	yes	Trace	RU	
B3C	Ncweng	School	Ncweng Primary School	Soil	25.03.04		Poor	yes	Trace	RU	
GMP69-1	Pietboos	Residence	House No 69	Soil	18.11.04	no			NAD	RU	1978
GMP69-3	Pietboos	Residence	House No 69	Soil	18.11.04	no			NAD	RU	1978
GMP69-6	Pietboos	Residence	House No 69	Foundation slab material	18.11.04	no			NAD	RU	1978
GMP69-7	Pietboos	Residence	House No 69	Plaster	18.11.04	no			NAD	RU	1978
GMP42-1	Pietboos	Residence	House No 42	Roof	18.11.04	no			NAD	RU	1993
GMP69-2	Pietboos	Residence	House No 69	Soil	18.11.04	yes			1-3% crocid	RU	1978
GMP69-4	Pietboos	Residence	House No 69	Soil	18.11.04	yes			Trace	RU	1978
GMP69-5	Pietboos	Residence	House No 69	Block	18.11.04	yes			1-3% crocid	RU	1978
GMP42-2	Pietboos	Residence	House No 42	Roof	18.11.04	yes			>50% crocid & chrys	RU	1993
P1	Pomfret	Residence	Esparanza Village Site	Block	20.10.04	no			NAD	RU	
P2	Pomfret	Residence	Esparanza Village Site	Roof	20.10.04	no			NAD	RU	
P3	Pomfret	Residence	Esparanza Village Site	Plaster	20.10.04	no			NAD	RU	
P4	Pomfret	Residence	Esparanza Village Site	Interior sheet rock	20.10.04	no			NAD	RU	
P5	Pomfret	Residence	Esparanza Village Site	Soil	20.10.04	no	Poor		NAD	RU	
Visible	Pomfret	Residence	Esparanza Village Site	Insulation	20.10.04	no			Pink fiberglass	RU	
Location	Pomfret	Mine Site	Gefco Mill Site-Pomfret	Mill Site	20.10.04	yes			No Sample		
P6	Pomfret	Rehabilitated Dump	Esparanza Village Dump Site	Soil	20.10.04	yes	Poor		Trace	RU	
P7	Pomfret	Rehabilitated Dump	Esparanza Village Dump Site	Soil	20.10.04	yes	Poor		Trace	RU	
Location	Pomfret	Rehabilitated	Pomfret Dump Site	Soil	20.10.04	yes	Poor		N/A		

		Dump								
GSD-OT1	Sedibeng	Residence	House No 290E	Building material	25.11.04	no	no	>30%	RU	1999
GSD-TS4	Sedibeng	Residence	House No 280	Soil	23.11.04	no		Trace	RU	1985
GSD-VK2	Sedibeng	Residence	House No 325	Soil	25.11.04	no		NAD	RU	1968
GSD-VK4	Sedibeng	Residence	House No 325	Soil	25.11.04	no		NAD	RU	1968
GSD-VK5	Sedibeng	Residence	House No 325	Soil	25.11.04	no		NAD	RU	1968
GSD-ED3	Sedibeng	Residence	House No 234	Soil	25.11.04	no		Trace	RU	1975
GSD-ED4	Sedibeng	Residence	House No 234	Soil	25.11.04	no		NAD	RU	1975
GSD-ED6	Sedibeng	Residence	House No 234	Foundation slab material	25.11.04	no		NAD	RU	1975
GSD-KN4	Sedibeng	Residence	House No 301	Soil	25.11.04	no		Trace	RU	1983
GMD-BS4	Sedibeng	Residence	House No 519	Soil	24.11.04	no		Trace	RU	1975
GSD-DM3	Sedibeng	Residence	House No 296A	Soil	23.11.04	no		Trace	RU	1965
GSD-DM5	Sedibeng	Residence	House No 296A	Soil	23.11.04	no		Trace	RU	1965
GSD-MP1	Sedibeng	Residence	House No 276A	Soil	23.11.04	no		NAD	RU	1969
GSD-MP2	Sedibeng	Residence	House No 276A	Soil	23.11.04	no		Trace	RU	1969
GSD-MP3	Sedibeng	Residence	House No 276A	Soil	23.11.04	no		NAD	RU	1969
GSD-MS1	Sedibeng	Residence	House No 288	Soil	23.11.04	no		Trace	RU	1969
GSD-MS2	Sedibeng	Residence	House No 288	Soil	23.11.04	no		NAD	RU	1969
GSD-MS3	Sedibeng	Residence	House No 288	Soil	23.11.04	no		Trace	RU	1969
GSD-MS4	Sedibeng	Residence	House No 288	Soil	23.11.04	no		NAD	RU	1969
GSD-MS5	Sedibeng	Residence	House No 288	Soil	23.11.04	no		Trace	RU	1969
GSD-MM2	Sedibeng	Residence	House No 287	Soil	23.11.04	no		NAD	RU	1987
GSD-MM3	Sedibeng	Residence	House No 287	Soil	23.11.04	no		Trace	RU	1987
GSD-MM4	Sedibeng	Residence	House No 287	Soil	23.11.04	no		NAD	RU	1987
GSD-MM5	Sedibeng	Residence	House No 287	Building material	23.11.04	no		>80%	RU	1987
GSD-KB1	Sedibeng	Residence	House No 181	Foundation slab material	24.11.04	no		NAD	RU	2003
GSD-JM2	Sedibeng	Residence	House No 245	Soil	25.11.04	no		NAD	RU	1990
GSD-JM3	Sedibeng	Residence	House No 245	Soil	25.11.04	no		NAD	RU	1990
GSD-JM4	Sedibeng	Residence	House No 245	Soil	25.11.04	no		NAD	RU	1990
GSD-JM5	Sedibeng	Residence	House No 245	Foundation slab material	25.11.04	no		NAD	RU	1990
GSD-DB1	Sedibeng	Residence	House No 220	Soil	24.11.04	no		Trace	RU	1998
GSD-DB2	Sedibeng	Residence	House No 220	Soil	24.11.04	no		Trace	RU	1998
GSD-DB3	Sedibeng	Residence	House No 220	Soil	24.11.04	no		NAD	RU	1998
GSD-PS1	Sedibeng	School	Ga-Mopedi Sedibeng Primary School	Soil	24.11.04	no		1-3% crocid	RU	1975
GSD-PS2	Sedibeng	School	Ga-Mopedi Sedibeng Primary School	Soil	24.11.04	no		Trace	RU	1975
GSD-PS3	Sedibeng	School	Ga-Mopedi Sedibeng Primary School	Soil	24.11.04	no		Trace	RU	1975
GSD-PS4	Sedibeng	School	Ga-Mopedi Sedibeng Primary School	Soil	24.11.04	no		Trace	RU	1975
GSD-PS5	Sedibeng	School	Ga-Mopedi Sedibeng Primary School	Soil	24.11.04	no		NAD	RU	1975

GSD-DT1	Sedibeng	Residence	House No 293	Building material	25.11.04	no	no	10-30% crocid	RU	1999
GSD-KM2	Sedibeng	Residence	House No 299	Soil	25.11.04	no		Trace	RU	1960
GSD-KM4	Sedibeng	Residence	House No 299	Soil	25.11.04	no		NAD	RU	1960
GSB-OB1	Sedibeng	Church	Church No 225B	Soil	24.11.04	no		NAD	RU	1998
GSB-OB4	Sedibeng	Church	Church No 225B	Soil	24.11.04	no		Trace	RU	1998
GSB-OB6	Sedibeng	Church	Church No 225B	Foundation slab material	24.11.04	no		NAD	RU	1998
GSD-TO1	Sedibeng	Residence	House No 193B	Soil	24.11.04	no		Trace	RU	1990
GSD-TO2	Sedibeng	Residence	House No 193B	Soil	24.11.04	no		NAD	RU	1990
GSD-TO3	Sedibeng	Residence	House No 193B	Soil	24.11.04	no		NAD	RU	1990
GSD-TO4	Sedibeng	Residence	House No 193B	Soil	24.11.04	no		NAD	RU	1990
GSD-TO5	Sedibeng	Residence	House No 193B	Foundation slab material	24.11.04	no	no	3-5% crocid	RU	1990
GSD-PT2	Sedibeng	Residence	House No 311	Soil	23.11.04	no		NAD	RU	1970
GSD-PT3	Sedibeng	Residence	House No 311	Soil	23.11.04	no		NAD	RU	1970
GSD-TS1	Sedibeng	Residence	House No 280	Soil	23.11.04	yes		Trace	RU	1985
GSD-TS2	Sedibeng	Residence	House No 280	Soil	23.11.04	yes		Trace	RU	1985
GSD-TS3	Sedibeng	Residence	House No 280	Soil	23.11.04	yes		Trace	RU	1985
GSD-TS5	Sedibeng	Residence	House No 280	Block	23.11.04	yes	no	1-3% crocid	RU	1985
GSD-VK1	Sedibeng	Residence	House No 325	Soil	25.11.04	yes		Trace	RU	1968
GSD-VK3	Sedibeng	Residence	House No 325	Soil	25.11.04	yes		Trace	RU	1968
GSD-VK6	Sedibeng	Residence	House No 325	Block	25.11.04	yes		3-5% crocid	RU	1968
GSD-ED1	Sedibeng	Residence	House No 234	Soil	25.11.04	yes		Trace	RU	1975
GSD-ED2	Sedibeng	Residence	House No 234	Soil	25.11.04	yes		Trace	RU	1975
GSD-ED5	Sedibeng	Residence	House No 234	Block	25.11.04	yes	no	1-3% crocid	RU	1975
GSD-KN1	Sedibeng	Residence	House No 301	Soil	25.11.04	yes		Trace	RU	1983
GSD-KN2	Sedibeng	Residence	House No 301	Soil	25.11.04	yes		Trace	RU	1983
GSD-KN3	Sedibeng	Residence	House No 301	Soil	25.11.04	yes		Trace	RU	1983
GSD-KN5	Sedibeng	Residence	House No 301	Block	25.11.04	yes	no	5-10%	RU	1983
GMD-BS1	Sedibeng	Residence	House No 519	Soil	24.11.04	yes		NAD	RU	1975
GMD-BS2	Sedibeng	Residence	House No 519	Soil	24.11.04	yes		Trace	RU	1975
GMD-BS3	Sedibeng	Residence	House No 519	Soil	24.11.04	yes		Trace	RU	1975
GMD-BS5	Sedibeng	Residence	House No 519	Foundation slab material	24.11.04	yes		1-3%	RU	1975
GMD-BS6	Sedibeng	Residence	House No 519	Block	24.11.04	yes		5-10%	RU	1975
GMD-BS7	Sedibeng	Residence	House No 519	Mortar	24.11.04	yes		10-20%	RU	1975
GSDG1	Sedibeng	Graveyard	Graveyard	Block	24.11.04	yes	no	5-10%	RU	1965
GSD-DM1	Sedibeng	Residence	House No 296A	Soil	23.11.04	yes		1-3%	RU	1965
GSD-DM2	Sedibeng	Residence	House No 296A	Soil	23.11.04	yes		5-10%	RU	1965
GSD-DM4	Sedibeng	Residence	House No 296A	Soil	23.11.04	yes		Trace	RU	1965
GSD-DM6	Sedibeng	Residence	House No 296A	Mortar	23.11.04	yes	yes	>10%	RU	1965

GSD-DM7	Sedibeng	Residence	House No 296A	Foundation slab material	23.11.04	yes	yes	>10%	RU	1965
GSD-MP4	Sedibeng	Residence	House No 276A	Soil	23.11.04	yes		Trace	RU	1969
GSD-MP5	Sedibeng	Residence	House No 276A	Soil	23.11.04	yes		>10%	RU	1969
GSD-MM1	Sedibeng	Residence	House No 287	Soil	23.11.04	yes		Trace	RU	1987
GSD-JM1	Sedibeng	Residence	House No 245	Soil	25.11.04	yes		5-10%	RU	1990
GSD-DB4	Sedibeng	Residence	House No 220	Soil	24.11.04	yes		NAD	RU	1998
GSD-DB5	Sedibeng	Residence	House No 220	Block	24.11.04	yes	no	>10%	RU	1998
GSD-PS6	Sedibeng	School	Ga-Mopedi Sedibeng Primary School	Foundation slab material	24.11.04	yes	no	5-10%	RU	1975
GSD-PS7	Sedibeng	School	Ga-Mopedi Sedibeng Primary School	Block	24.11.04	yes	no	10-30%	RU	1975
GSD-KM1	Sedibeng	Residence	House No 299	Soil	25.11.04	yes		NAD	RU	1960
GSD-KM3	Sedibeng	Residence	House No 299	Soil	25.11.04	yes		Trace	RU	1960
GSB-OB2	Sedibeng	Church	Church No 225B	Soil	24.11.04	yes		Trace	RU	1998
GSB-OB3	Sedibeng	Church	Church No 225B	Soil	24.11.04	yes		Trace	RU	1998
GSB-OB5	Sedibeng	Church	Church No 225B	Block	24.11.04	yes		5-10% crocid	RU	1998
GSD-TO6	Sedibeng	Residence	House No 193B	Block	24.11.04	yes	yes	10-15% crocid	RU	1990
GSD-PT1	Sedibeng	Residence	House No 311	Soil	23.11.04	yes		1-3% crocid	RU	1970
GSD-PT4	Sedibeng	Residence	House No 311	Soil	23.11.04	yes		Trace	RU	1970
GSD-PT5	Sedibeng	Residence	House No 311	Block	23.11.04	yes	yes	30-40% crocid	RU	1970
SC-1	Seodin	Hospital/Clinic	Seodin Block B	Soil	20.04.05			Trace	RU	1975
SC-2	Seodin	Hospital/Clinic	Seodin Block B	Soil	20.04.05			NAD	RU	1975
SC-3	Seodin	Hospital/Clinic	Seodin Block B	Soil	20.04.05			NAD	RU	1975
MMPS-1	Seodin	School	Mahube-A-Mosho Pre-School	Soil	20.04.05			NAD	RU	1986
MMPS-2	Seodin	School	Mahube-A-Mosho Pre-School	Soil	20.04.05			NAD	RU	1986
MMPS-3	Seodin	School	Mahube-A-Mosho Pre-School	Soil	20.04.05			NAD	RU	1986
MMPS-4	Seodin	School	Mahube-A-Mosho Pre-School	Soil	20.04.05			NAD	RU	1986
MMPS-5	Seodin	School	Mahube-A-Mosho Pre-School	Foundation slab material	20.04.05			NAD	RU	1986
KPS-1	Seodin	School	Kudumane Primary School	Soil	20.04.05			NAD	RU	1961
KPS-2	Seodin	School	Kudumane Primary School	Bricks	20.04.05			NAD	RU	1961
KPS-3	Seodin	School	Kudumane Primary School	Plaster	20.04.05		yes	10-15% crocid	RU	1961
KPS-4	Seodin	School	Kudumane Primary School	Soil	20.04.05			NAD	RU	1961
MC-1	Seodin	Private business	Mabejane Café	Soil	20.04.05			Trace	RU	1976
MC-2	Seodin	Private business	Mabejane Café	Soil	20.04.05			NAD	RU	1976
MC-3	Seodin	Private business	Mabejane Café	Soil	20.04.05			NAD	RU	1976
WM236-1	Seodin	Residence	Block D House No 236	Bricks	20.04.05		yes	5-10% crocid	RU	1960
WM236-2	Seodin	Residence	Block D House No 236	Soil	20.04.05			Trace	RU	1960
WM236-3	Seodin	Residence	Block D House No 236	Soil	20.04.05			Trace	RU	1960
HA244-1	Seodin	Residence	House No E244 Block D	Soil	20.04.05			NAD	RU	1960
HA244-2	Seodin	Residence	House No E244 Block D	Soil	20.04.05			NAD	RU	1960

HA244-3	Seodin	Residence	House No E244 Block D	Soil	20.04.05			NAD	RU	1960
HA244-4	Seodin	Residence	House No E244 Block D	Plaster	20.04.05			NAD	RU	1960
SMR236-1	Seodin	Road	Seodin Main Road	Soil	20.04.05			3-5% crocid	RU	
SMR236-2	Seodin	Road	Seodin Main Road	Soil	20.04.05			3-5% crocid	RU	
AT166-1	Seodin	Residence	House No E 166 Block D	Soil	20.04.05			NAD	RU	1990
AT166-2	Seodin	Residence	House No E 166 Block D	Soil	20.04.05			NAD	RU	1990
AT166-3	Seodin	Residence	House No E 166 Block D	Soil	20.04.05			NAD	RU	1990
AT166-4	Seodin	Residence	House No E 166 Block D	Soil	20.04.05			NAD	RU	1990
SSG-1	Seodin	Open space	Seodin sports ground	Soil	21.04.05			NAD	RU	
SSG-2	Seodin	Open space	Seodin sports ground	Soil	21.04.05			NAD	RU	
SSG-3	Seodin	Open space	Seodin sports ground	Soil	21.04.05			NAD	RU	
SM-1	Seodin	Private business	Minimarket	Soil	21.04.05			NAD	RU	1960
SM-2	Seodin	Private business	Minimarket	Soil	21.04.05			NAD	RU	1960
SM-3	Seodin	Private business	Minimarket	Foundation slab material	21.04.05			NAD	RU	1960
SM-4	Seodin	Private business	Minimarket	Bricks	21.04.05			NAD	RU	1960
YC-1	Seodin	Private business	Yarona Café	Soil	21.04.05			NAD	RU	1964
YC-2	Seodin	Private business	Yarona Café	Soil	21.04.05			NAD	RU	1964
YC-3	Seodin	Private business	Yarona Café	Foundation slab material	21.04.05			NAD	RU	1964
YC-4	Seodin	Private business	Yarona Café	Soil	21.04.05			NAD	RU	1964
SM-MH1	Seven Miles	Residence	House No E75	Soil	09.12.04	no		Trace	RU	1979
SM-MH4	Seven Miles	Residence	House No E75	Plaster	09.12.04	no		NAD	RU	1979
SM-JO1	Seven Miles	Residence	House No E62	Soil	08.12.04	no		Trace	RU	1967
SM-JO2	Seven Miles	Residence	House No E62	Foundation slab material	08.12.04	no		NAD	RU	1967
SM-JO3	Seven Miles	Residence	House No E62	Bricks	08.12.04	no		NAD	RU	1967
SM-JM1	Seven Miles	Residence	Block A House No E153	Soil	08.12.04	no		Trace	RU	1979
SM-JM2	Seven Miles	Residence	Block A House No E153	Bricks	08.12.04	no		NAD	RU	1979
SM-JM3	Seven Miles	Residence	Block A House No E153	Foundation slab material	08.12.04	no		NAD	RU	1979
SM-LM1	Seven Miles	Residence	House No E140	Soil	08.12.04	no		Trace	RU	
SM-LM2	Seven Miles	Residence	House No E140	Bricks	08.12.04	no		NAD	RU	
SM-JK1	Seven Miles	Residence	House No E30	Soil	09.12.04	no		NAD	RU	1997
SM-JK2	Seven Miles	Residence	House No E30	Soil	09.12.04	no		NAD	RU	1997
SM-WP1	Seven Miles	Residence	House No 1386 Windmill Pump	Soil	08.12.04	no		NAD	RU	
SM-WP2	Seven Miles	Residence	House No 1386 Windmill Pump	Bricks	08.12.04	no		NAD	RU	
SM-MH2	Seven Miles	Residence	House No E75	Bricks	09.12.04	yes	no	10-20% crocid	RU	1979
SM-MH3	Seven Miles	Residence	House No E75	Foundation slab material	09.12.04	yes	yes	1-3% crocid	RU	1979
GMSL-TS2	Sloja	Residence	House No 16	Soil	02.12.04	no		Trace	RU	1979
GSSMR1	Sloja	Road	Sedibeng Main Road	Soil	02.12.04	no		NAD	RU	
GMSL-GM1	Sloja	Residence	House No B9	Soil	02.12.04	no		Trace	RU	1985

GMSL-GM2	Sloja	Residence	House No B9	Soil	02.12.04	no		NAD	RU	1985
GMSL-GM3	Sloja	Residence	House No B9	Soil	02.12.04	no		NAD	RU	1985
GMSL-GM4	Sloja	Residence	House No B9	Soil	02.12.04	no		NAD	RU	1985
GSGMR1	Sloja	Road	Sloja Main Road	Soil	02.12.04	yes		Trace	RU	1979
GMSL-TS1	Sloja	Residence	House No 16	Soil	02.12.04	yes		1-3% crocid	RU	1979
GMSL-TS3	Sloja	Residence	House No 16	Soil	02.12.04	yes		Trace	RU	1979
GMSL-TS4	Sloja	Residence	House No 16	Soil	02.12.04	yes		Trace	RU	1979
GMSL-TS5	Sloja	Residence	House No 16	Concrete	02.12.04	yes	no	5-10% crocid	RU	1979
GMSL-TS6	Sloja	Residence	House No 16	Plaster	02.12.04	yes	yes	30-40% crocid	RU	1979
GMSL-TS7	Sloja	Residence	House No 16	Block	02.12.04	yes	no	5-10% crocid	RU	1979
GMSL-TS8	Sloja	Residence	House No 16	Floor	02.12.04	yes		5-10% crocid	RU	1979
GMSL-TS9	Sloja	Residence	House No 16	Foundation slab material	02.12.04	yes		1-3% crocid	RU	1979
TLL55-1	Tshukudung	Residence	House No 55	Soil	26.04.05			NAD	RU	2003
TLL55-2	Tshukudung	Residence	House No 55	Soil	26.04.05			NAD	RU	2003
TLL55-3	Tshukudung	Residence	House No 55	Soil	26.04.05			NAD	RU	2003
TLL55-4	Tshukudung	Residence	House No 55	Soil	26.04.05			NAD	RU	2003
TLL55-5	Tshukudung	Residence	House No 55	Block	26.04.05		no	3-5% crocid	RU	2003
TMB-1	Tshukudung	Residence	Tshukudung village	Soil	26.04.05			NAD	RU	1990
TMB-2	Tshukudung	Residence	Tshukudung village	Soil	26.04.05			NAD	RU	1990
TMB-3	Tshukudung	Residence	Tshukudung village	Soil	26.04.05			NAD	RU	1990
TMB-4	Tshukudung	Residence	Tshukudung village	Soil	26.04.05			NAD	RU	1990
TMB-5	Tshukudung	Residence	Tshukudung village	Block	26.04.05		no	1-3% crocid	RU	1990
TZCC-1	Tshukudung	Church	Zion Camp Church	Soil	26.04.05			NAD	RU	1980
TZCC-2	Tshukudung	Church	Zion Camp Church	Soil	26.04.05			NAD	RU	1980
TZCC-3	Tshukudung	Church	Zion Camp Church	Soil	26.04.05			NAD	RU	1980
TZCC-4	Tshukudung	Church	Zion Camp Church	Soil	26.04.05			NAD	RU	1980
TZCC-5	Tshukudung	Church	Zion Camp Church	Concrete	26.04.05			3-5% crocid	RU	1980
TPS-1	Tshukudung	School	Primary School	Soil	26.04.05		no	NAD	RU	1995
TPS-2	Tshukudung	School	Primary School	Soil	26.04.05	no		NAD	RU	1995
TPS-3	Tshukudung	School	Primary School	Soil	26.04.05			NAD	RU	1995
TPS-4	Tshukudung	School	Primary School	Soil	26.04.05			NAD	RU	1995
TPS-5	Tshukudung	School	Primary School	Block	26.04.05	no		NAD	RU	1995
TPS-6	Tshukudung	School	Primary School	Mortar	26.04.05			NAD	RU	1995
TMB26-1	Tshukudung	Residence	House No 26	Soil	26.04.05			NAD	RU	1978
TMB26-2	Tshukudung	Residence	House No 26	Soil	26.04.05			NAD	RU	1978
TMB26-3	Tshukudung	Residence	House No 26	Soil	26.04.05			NAD	RU	1978
TMB26-4	Tshukudung	Residence	House No 26	Soil	26.04.05			NAD	RU	1978
TGT-1	Tshukudung	Residence	House No A54	Soil	26.04.05			NAD	RU	2003

TGT-2	Tshukudung	Residence	House No A54	Soil	26.04.05				NAD	RU	2003
TGT-3	Tshukudung	Residence	House No A54	Soil	26.04.05				NAD	RU	2003
TGT-4	Tshukudung	Residence	House No A54	Soil	26.04.05				NAD	RU	2003
TGT-5	Tshukudung	Residence	House No A54	Block	26.04.05			no	20-30% crocid	RU	2003
TCR-1	Tshukukung	Road	Public Road Ishukudung Village	Soil	26.04.05				NAD	RU	
TCMR-1	Tshukukung	Road	Public Road Ishukudung Village	Soil	26.04.05				NAD	RU	
T-EL 388b-1	Tsimeng	Residence	Tsineng P. Station	Soil	18.04.05				NAD	RU	1974
TSS-166-1	Tsineng	Residence	Tsineng Block E 166E	Block	20.04.05	yes			30-50% crocid	RU	1982
T-EL 388b-2	Tsineng	Residence	Tsineng P. Station	Soil	18.04.05				NAD	RU	1974
T-EL 388b-3	Tsineng	Residence	Tsineng P. Station	Soil	18.04.05				NAD	RU	1974
T-EL 388b-4	Tsineng	Residence	Tsineng P. Station	Soil	18.04.05				NAD	RU	1974
T-LK 389b-1	Tsineng	Residence	Tsineng P. Station	Soil	18.04.05				NAD	RU	1978
T-LK 389b-2	Tsineng	Residence	Tsineng P. Station	Soil	18.04.05				NAD	RU	1978
T-LK 389b-3	Tsineng	Residence	Tsineng P. Station	Soil	18.04.05				NAD	RU	1978
T-LK 389b-4	Tsineng	Residence	Tsineng P. Station	Soil	18.04.05				NAD	RU	1978
T-LK 389b-5	Tsineng	Residence	Tsineng P. Station	Block	18.04.05		Poor		1-3% crocid	RU	1978
TJS 390 g - 1	Tsineng	Residence	Tsineng P. Station	Soil	18.04.05				NAD	RU	1978
TJS 390 g - 2	Tsineng	Residence	Tsineng P. Station	Soil	18.04.05				NAD	RU	1978
TJS 390 g - 3	Tsineng	Residence	Tsineng P. Station	Soil	18.04.05				NAD	RU	1978
TJS 390 g - 4	Tsineng	Residence	Tsineng P. Station	Soil	18.04.05				Trace	RU	1978
TJS 390 g - 5	Tsineng	Residence	Tsineng P. Station	Block	18.04.05		Poor		20-30% crocid	RU	1978
T-AS 235e - 1	Tsineng	Residence	Tsineng Village	Block	20.04.05		Poor	yes	10-20% crocid	RU	1982
T-AS 235e - 2	Tsineng	Residence	Tsineng Village	Foundation	20.04.05		Poor	no	20-30% crocid	RU	1982
JM25-1	Vergenoeg	Residence	House No E25	Bricks	15.04.05	yes			20-30% crocid	RU	1993
JM25-2	Vergenoeg	Residence	House No E25	Foundation slab material	15.04.05	no			NAD	RU	1993
JM25-3	Vergenoeg	Residence	House No E25	Roof	15.04.05	yes			80% chry & croc	RU	1993
JM25-4	Vergenoeg	Residence	House No E25	Soil	15.04.05	no			NAD	RU	1993
JM25-5	Vergenoeg	Residence	House No E25	Soil	15.04.05	no			NAD	RU	1993
RPS-1	Vergenoeg	School	Rearata Primary School	Mortar	15.04.05				20-30% crocid	RU	1983
RPS-2	Vergenoeg	School	Rearata Primary School	Soil	15.04.05				NAD	RU	1983
RPS-3	Vergenoeg	School	Rearata Primary School	Soil	15.04.05				NAD	RU	1983
RPS-4	Vergenoeg	School	Rearata Primary School	Soil	15.04.05				NAD	RU	1983
RPS-5	Vergenoeg	School	Rearata Primary School	Soil	15.04.05				NAD	RU	1983
TBS250-1	Vergenoeg	Private business	Thusanang Bottle Store	Bricks	15.04.05				NAD	RU	1965
TBS250-2	Vergenoeg	Private business	Thusanang Bottle Store	Soil	15.04.05				NAD	RU	1965
TBS250-3	Vergenoeg	Private business	Thusanang Bottle Store	Soil	15.04.05				NAD	RU	1965
TBS250-4	Vergenoeg	Private business	Thusanang Bottle Store	Soil	15.04.05				NAD	RU	1965

TBS250-5	Vergenoeg	Private business	Thusanang Bottle Store	Foundation slab material	15.04.05			NAD	RU	1965
PM21-1	Vergenoeg	Residence	House No E21	Soil	15.04.05	no		NAD	RU	1984
PM21-2	Vergenoeg	Residence	House No E21	Soil	15.04.05	no		NAD	RU	1984
PM21-3	Vergenoeg	Residence	House No E21	Soil	15.04.05	no		NAD	RU	1984
PM21-4	Vergenoeg	Residence	House No E21	Bricks	15.04.05	no		NAD	RU	1984
CSG-1	Vergenoeg	Open space	Community Sports Ground	Soil	15.04.05			NAD	RU	
CSG-2	Vergenoeg	Open space	Community Sports Ground	Soil	15.04.05			NAD	RU	
CSG-3	Vergenoeg	Open space	Community Sports Ground	Soil	15.04.05			NAD	RU	
CSG-4	Vergenoeg	Open space	Community Sports Ground	Soil	15.04.05			NAD	RU	
CSG-5	Vergenoeg	Open space	Community Sports Ground	Soil	15.04.05			NAD	RU	
CSG-6	Vergenoeg	Open space	Community Sports Ground	Soil	15.04.05			NAD	RU	
CSG-7	Vergenoeg	Open space	Community Sports Ground	Soil	15.04.05			NAD	RU	
GDCC83-1	Vergenoeg	Public Buildings	Gaboamogwe Day Care Centre	Soil	15.04.05			NAD	RU	1992
GDCC83-2	Vergenoeg	Public Buildings	Gaboamogwe Day Care Centre	Soil	15.04.05			Trace	RU	1992
GDCC83-3	Vergenoeg	Public Buildings	Gaboamogwe Day Care Centre	Soil	15.04.05			NAD	RU	1992
GDCC83-4	Vergenoeg	Public Buildings	Gaboamogwe Day Care Centre	Soil	15.04.05			NAD	RU	1992
VMSR-1	Vergenoeg	Road	Main Street road	Soil	15.04.05			1-3% crocid	RU	
VMSR-2	Vergenoeg	Road	Main Street road	Soil	15.04.05			Trace	RU	
VMSR-3	Vergenoeg	Road	Main Street road	Soil	15.04.05			NAD	RU	
VMSR-4	Vergenoeg	Road	Main Street road	Soil	15.04.05			NAD	RU	
FM22-1	Vergenoeg	Residence	House No E22	Bricks	13.04.05		no	3-5% crocid	RU	1983
FM22-2	Vergenoeg	Residence	House No E22	Soil	13.04.05			NAD	RU	1983
FM22-3	Vergenoeg	Residence	House No E22	Soil	13.04.05			NAD	RU	1983
FM22-4	Vergenoeg	Residence	House No E22	Foundation slab material	13.04.05		yes	30-50% crocid	RU	1983
WCR-1	Wandrag	Road	Public Road	Soil	29.04.05	yes		1-3% crocid	RU	
WCR-2	Wandrag	Road	Public Road	Rock	29.04.05	yes		Trace	RU	
WJR16-1	Wandrag	Residence	House No 16	Soil	29.04.05			3-5% crocid	RU	1964
WJR16-2	Wandrag	Residence	House No 16	Soil	29.04.05			Trace	RU	1964
WJR16-3	Wandrag	Residence	House No 16	Soil	29.04.05			Trace	RU	1964
WJR16-4	Wandrag	Residence	House No 16	Soil	29.04.05			NAD	RU	1964
WJR16-5	Wandrag	Residence	House No 16	Block	29.04.05			20-30% crocid	RU	1964
WJR16-6	Wandrag	Residence	House No 16	Roof	29.04.05			>50% crocid	RU	1964
WJR16-7	Wandrag	Residence	House No 16	Foundation slab material	29.04.05			20-30% crocid	RU	1964
WMVZ-1	Wandrag	Residence	House No 18	Soil	29.04.05			Trace	RU	1964
WMVZ-2	Wandrag	Residence	House No 18	Soil	29.04.05			Trace	RU	1964
WMVZ-3	Wandrag	Residence	House No 18	Soil	29.04.05			Trace	RU	1964
WMVZ-4	Wandrag	Residence	House No 18	Soil	29.04.05			Trace	RU	1964
WMVZ-5	Wandrag	Residence	House No 18	Block	29.04.05		yes	5-10% crocid	RU	1964

WMVZ-6	Wandrag	Residence	House No 18	Roof	29.04.05		no	>50% croc. & chrys.	RU	1964
WMVZ-7	Wandrag	Residence	House No 18	Plaster	29.04.05		yes	20-30% crocid	RU	1964
WWG-1	Wandrag	Residence	House No 7	Soil	29.04.05	yes		>50% crocid	RU	1964
WWG-2	Wandrag	Residence	House No 7	Soil	29.04.05	no		NAD	RU	1964
WWG-3	Wandrag	Residence	House No 7	Soil	29.04.05	yes		1-3% crocid	RU	1964
WWG-4	Wandrag	Residence	House No 7	Soil	29.04.05	yes		Trace	RU	1964
WWG-5	Wandrag	Residence	House No 7	Block	29.04.05	yes		30-50% crocid	RU	1964