DEVELOPMENT OF A METHODOLOGY FOR THE DELINEATION OF AIR QUALITY MANAGEMENT AREAS IN SOUTH AFRICA

By

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Abstract

Since 1992 the Department of Environmental Affairs and Tourism (DEAT), now the Department of Environmental Affairs (DEA), acknowledged that pollution and waste management governance was inadequate in dealing with South Africa's changing social and industrial context. This triggered an extensive legislative revision, with the new National Environmental Management: Air Quality Act (No. 39 of 2004) (AQA) being partially implemented on 11 September 2005 and full implementation expected by 1 April 2010.

The goal of this research was to develop a methodology for the delineation of the boundaries of air quality management areas in South Africa. The preliminary objective of the research was to identify the specific criteria that should be considered when developing the methodology. A review of the methodologies used internationally was undertaken, looking specifically at regions and countries with similar effects-based air quality legislation. The review concluded that the international practice regarding boundary determination was data intensive, relying heavily on the results of ambient air quality monitoring and the results of dispersion modelling based on comprehensive emissions inventories. Another commonality between the methodologies was the use of administrative boundaries as the borders of air quality management areas. South Africa has limited ambient air quality monitoring and there is no national emissions inventory for criteria pollutants. In the absence of this information an alternative approach was required. The next objective of the research was to identify or develop a proxy methodology for assessing the impact of each of these criteria to be used in the boundary determination. The criteria assessed as part of this research included, population density, emission criteria (industrial, mining and domestic), topography and administrative boundaries. A further objective of the research was to combine all the criteria to produce a single indicator or value as to the air pollution impact potential of the area under consideration. This methodology was then applied in the South African context. The final objective of the research was to assess the results of the application of the methodology on the regulatory framework proposed by the AQA, at the national, provincial and local government levels.

The methodology has proved successful in the identification of areas with high air pollution impact potential in South Africa. This has allowed for a review of the boundaries proclaimed for the Vaal Triangle Airshed Priority Area and the Highveld Priority Area. In both cases significant revisions of the boundaries are recommended, however due to the controversial nature of these recommendations, it is proposed that these revisions are deferred until the five-

yearly review phase of the priority area management plan. The results also recommended the proclamation of two additional national priority areas. The first was the proposed Magaliesberg Priority Area, which covers the north-western areas of Gauteng and the eastern areas of the North-West. This area combines the high density residential, commercial and industrial areas of Gauteng with the high density mining and industrial areas of the North-West. However, it is recommended that further ambient air quality monitoring and research is required prior to the proclamation of this national priority area. The second new national priority area proposed is the Waterberg Priority Area. This proclamation is a proactive declaration based on the proposed industrial developments earmarked for this area. Due to extensive coal reserves in the area, the development of additional coal-fired power generation, a coal to liquid facility and other coal beneficiation projects are currently under consideration.

The research has identified five potential provincial priority areas. The provincial priority areas are associated with the major metropolitan centres in the country and their adjacent district municipalities. All of the proposed provincial priority areas, with the exception of the one proposed in Gauteng, require further ambient air quality monitoring and research prior to their proclamation. It is recommended that the City of Johannesburg / City of Tshwane provincial priority area be considered for immediate declaration.

The review of the district and local municipalities identified in Table 24 of the National Framework highlighted the conservative nature of the initial assessment. The review amended the classification of 33 of the local municipalities, with 32 being reclassified downwards and only one being reclassified upwards. This also highlighted the subjective nature of the initial assessment. It is recommended that the local municipalities identified as having "Poor" or "Potentially Poor" air quality rating, be prioritised as potential sites in the national ambient air quality monitoring network and receive assistance in the development of their air quality management plans. This ensures that the limited financial and human resources assigned to air quality management in South Africa are deployed in those areas with the greatest need.

Preface

The work described in this thesis was carried out in the School of Environmental Sciences, University of KwaZulu-Natal, between July 2003 and May 2010, under the supervision of Professor Roseanne D. Diab, in fulfilment of the academic requirements for the degree of Doctor of Philosophy.

This study represents the original work undertaken by the author and has not been submitted in any other form to another university. Where use has been made of the work of others, it has been duly acknowledged in the text.

Declaration - Plagiarism

I, Gregory MacDonald Scott declare that

1. The research reported in this thesis, except where otherwise indicated, is my original research.

2. This thesis has not been submitted for any degree or examination at any other university.

3. This thesis does not contain other persons' data, pictures, graphs or other information, unless specifically acknowledged as being sourced from other persons.

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List of Acronyms

AAQ NEPM	Ambient Air Quality National Environmental Protection Measure
AQA	National Environmental Management: Air Quality Act
AQCAs	Air Quality Control Areas
AQCRs	Air Quality Control Regions
AQFD	Air Quality Framework Directive
AQM	Air Quality Management
AQMA	Air Quality Management Area
AQMP	Air Quality Management Plan
APCO	Air Pollution Control Officer
APPA	Atmospheric Pollution Prevention Act
BPM	Best Practicable Means
CAA	Clean Air Act
CAU	Census Area Unit
CAPCO	Chief Air Pollution Control Officer
CBOs	Community Based Organisations
CEM	Continuous Emission Monitoring
CH_4	Methane
C_4H_6	1,3-Butadiene
C_6H_6	Benzene
CO	Carbon Monoxide
CONNEPP	Consultative National Environmental Policy Process
CTL	Coal To Liquids
CSIR	Council for Scientific and Industrial Research
DEA	Department of Environmental Affairs
DEAT	Department of Environmental Affairs and Tourism
Defra	Department for Environment, Food and Rural Affairs
DEM	Digital Elevation Model
DETR	Department of Environment, Transport and the Regions
DMAs	District Management Areas
DME	Department of Minerals and Energy
DoE	Department of the Environment
DWA	Department of Water Affairs
EC	European Commission

EEA	European Environment Agency
EEA/ETC-ACC	European Environment Agency European Topic Centre on Air and Climate Change
EEC	European Economic Community
EMM	Ekurhuleni Metropolitan Municipality
EPAQS	Expert Panel on Air Quality Standards
ERC	Energy Research Centre
EU	European Union
FRIDGE	Fund for Research into Industrial Development Growth and Equity
GIS	Geographical Information System
HPA	Highveld Priority Area
IDP	Integrated Development Plan
IDZ	Industrial Development Zone
IGAE	Intergovernmental Agreement on the Environment
IP&WM	Integrated Pollution and Waste Management
IPC	Integrated Pollution Control
ISO	International Organisation for Standardisation
LAMAs	Local Air Management Areas
LAQM	Local Air Quality Management
LAT	Lower Assessment Threshold
LPG	Liquid Petroleum Gas
MEC	Member of the Executive Committee
MPA	Magaliesberg Priority Area
MoT	Ministry of Transport
NAAQS	National Ambient Air Quality Standards
NACA	National Association for Clean Air
NAPAC	National Air Pollution Advisory Committee
NAQAC	National Air Quality Advisory Committee
NAQMP	National Air Quality Management Programme
NAQO	National Air Quality Officer
NAQS	National Air Quality Strategy
NCOP	National Council of Provinces
NEC	National Emission Ceiling
NEMA	National Environmental Management Act
NEPC	National Environmental Protection Council

NEPMs	National Environmental Protection Measures
NGOs	Non-Governmental Organisations
NH_3	Ammonia
NMBMM	Nelson Mandela Bay Metropolitan Municipality
NO_2	Nitrogen Dioxide
NO_x	Oxides of Nitrogen
NPI	National Pollutant Inventory
NRC	National Research Council
NSCA	National Society for Clean Air and Environmental Protection
NZ	New Zealand
O_3	Ozone
PAQO	Provincial Air Quality Officer
Pb	Lead
PGM	Platinum Group Metals
$PM_{2.5}$	Particulate Matter with aerodynamic diameter less than 2.5 microns
PM_{10}	Particulate Matter with aerodynamic diameter less than 10 microns
PRC	Peer Review Committee
SAAQIS	South African Air Quality Information System
SA EPA	South Australia Environmental Protection Agency
SAFARI	South African Fire-Atmosphere Research Initiative
SANAS	South African National Accreditation System
SANRAL	South African National Roads Agency Limited
SAWS	South African Weather Service
SIP	State Implementation Plan
SO_2	Sulphur Dioxide
StatsSA	Statistics South Africa
TLA	Territorial Local Authority
UAT	Upper Assessment Threshold
UJ	University of Johannesburg
UK	United Kingdom
US	United States
US-EPA	United States Environmental Protection Agency
VKT	Vehicle Kilometre Travelled
VOCs	Volatile Organic Compounds
VTAPA	Vaal Triangle Airshed Priority Area

CHAPTER ONE

INTRODUCTION

1.1 Background

Since 1965 air quality management in South Africa has been regulated in terms of the Atmospheric Pollution Prevention Act (No. 45 of 1965) (APPA). This legislation employed a source-based approach, regulating major industrial, vehicle, smoke and dust emissions. A more detailed review of the legislation is provided later, suffice to say at this juncture, the legislation has proved ineffective in managing air quality in the Republic. This has allowed the development of air pollution "hotspots" across the country, namely the Vaal Triangle, Mpumalanga Highveld, South Durban, Milnerton and Richards Bay (Held *et al.*, 1996; Zunckel, 1999; Scorgie *et al.*, 2004a; Zunckel *et al.*, 2006a; Piekth *et al.*, 2006; Josipovic, 2009; DEA, 2009a). Figure 1.1 shows the location of the air pollution "hotspots" and the associated problem pollutants.

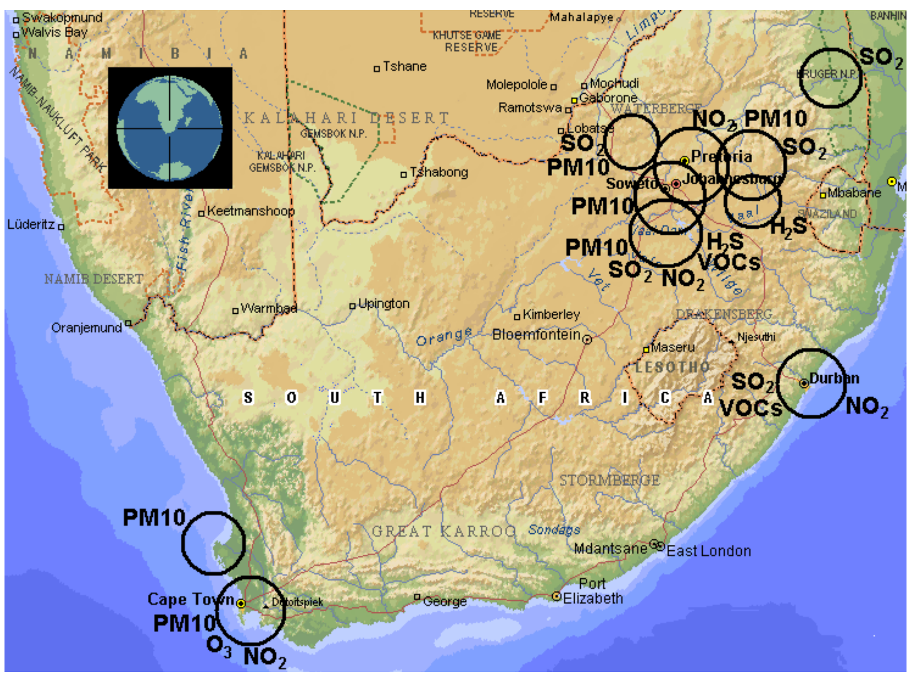

Figure 1.1 Location of the known air pollution "hotspots" in South Africa (Scorgie, 2005)

From 1992 it was acknowledged that South Africa's approach to pollution and waste management governance was inadequate (DEAT, 2000). The first major step in the transition to a new air quality management system was the drafting of the new Constitution (No. 108 of 1996) (Republic of South Africa Government, 1996). Section 24 of the Constitution states that:

"Everyone has the right –

a) to an environment that is not harmful to their health or well-being; and

b) to have the environment protected, for the benefit of present and future generations, through reasonable legislative and other measures that –

i. prevent pollution and ecological degradation;

ii. promote conservation; and

iii. secure ecologically sustainable development and use of natural resources while promoting justifiable economic and social development."

This right to environmental protection was the driving force behind subsequent environmental legislation in South Africa. The promulgation of the National Environmental Management Act (No. 107 of 1998) (NEMA) set out the framework for the current environmental legislation in the country (Republic of South Africa Government, 1998). The National Environmental Management: Air Quality Act (No. 39 of 2004) (AQA) is one part of the overall environmental management framework (Republic of South Africa Government, 2005). The AQA is a paradigm shift in terms of its approach to air quality management in South Africa. The air quality management philosophy moves from a source-based to an effects-based approach, with emphasis on the ambient environment (Scorgie, 2008). The AQA introduced new air quality management tools, including ambient air quality standards, emission standards, controlled emitters, controlled fuels and priority area management.

In terms of Schedule 4, Part B, the Constitution delegates the responsibility for air quality management from national to local government level (Republic of South Africa Government, 1996). This is a major departure from the status-quo where air quality management has been a national responsibility since 1965. The AQA is the enabling legislation that will see this transition of responsibility effected. The AQA was promulgated in 2005 and specific sections of the Act commenced on 9 September 2005. At the time, the Minister of Environmental Affairs and Tourism was not convinced that local government was adequately prepared to undertake the full air quality management function. As such, he held back all sections of the AQA that involved local government responsibility, specifically those relating to emission licencing. It was indicated that during a transitional process, both the AQA and the APPA would run concurrently, with emission licencing handled under the provisions of the APPA. The transitional period would allow for capacity building and skills development within local government to competently implement the AQA.

The AQA is also considered a framework piece of legislation, which contains guiding principle and policies. Section 7 of the AQA makes provision for the development of a National Framework for achieving the objectives of the Act. After a broadly consultative process the first generation National Framework was implemented on 11 September 2007 (DEAT, 2007a). The objective of the National Framework was to provide mechanisms, systems and procedures to promote holistic and integrated air quality management. Hence, the National Framework provided norms and standards for all technical aspects of air quality management in South Africa.

Section 5.3 of the National Framework looked specifically at air quality problem identification and prioritization in the Republic. The inclusion of Table 24 (Appendix 1), which listed metropolitan and district municipalities rated as having poor or potentially poor air quality, was seen as controversial, given that it was a subjective assessment based on limited scientific data (DEAT, 2007a). To address the perceived poor air quality in these areas the AQA makes provision for priority area management. The Minister or the provincial Member of the Executive Committee (MEC) may declare a priority area if the ambient air quality standards are being, or may be exceeded, and the area requires specific air quality management actions to rectify the situation. This air quality management tool has three strategic drivers (DEAT, 2006a). Firstly it allowed for the concentration of limited air quality management capacity (human, technical and financial) when dealing with acknowledged air pollution problem areas. Secondly it prescribed co-operative governance that may become problematic in areas where cross boundary air pollution problems existed. Finally it allowed for the application of holistic air quality management methodologies, namely airshed air quality management. The Act provides little guidance on the designation of the boundary of such priority areas. Section 5.4.6 of the National Framework covers air quality management planning matters but the document provides minimal guidance, other than referring to an air quality management planning document that was under development at the time of publication. A review of the final document (DEAT, 2008) reveals that minimal guidance is provided, other than recommending the use of administrative boundaries and topography as criteria for the designation of priority areas.

To date, two national priority areas have been declared. The Vaal Triangle Airshed Priority Area (VTAPA) was formally declared on 21 April 2006 and the Highveld Priority Area (HPA) was formally declared on 23 November 2007. During the declaration process, a boundary to each of these areas was proposed, but no specific methodology was utilized. The boundaries were delineated based on readily available data, namely outputs of dispersion modeling projects undertaken in the areas, limited ambient air quality data and administrative boundaries. The outputs of the VTAPA baseline assessment roughly concurred with the original delineation, however the boundary was challenged by Scott *et al.* (2005). Recently the baseline assessment for the HPA has been completed, so it was possible to assess the accuracy of the HPA delineation. The lack of a standard methodology to delineate the boundary is considered a short-coming of the process.

One of the major challenges facing air quality management officials is addressing these localised air quality management problems. A key to managing these areas is access to high quality air quality information. Unfortunately South Africa has relatively few ambient air quality monitoring stations. A comprehensive study was undertaken in 2004 to identify all ambient air quality monitoring stations in the country (DEA, 2009a). In total, 160 stations were identified and data were obtained from 136. Figures 1.2 – 1.4 shows the location of the ambient monitoring locations for the common pollutants on concern in South Africa, namely particulate matter, sulphur dioxide (SO_2) and oxides of nitrogen (NO_x). These figures highlight the paucity of ambient air quality information in South Africa, specifically in the western half of the country and those areas outside of urban centres. Concerns were raised regarding data quality since very few of the stations were South African National Accreditation System (SANAS) accredited to the ISO 17025 standard (DEA, 2009a). A more recent study was commissioned by the Department of Environmental Affairs (DEA) to survey all the ambient air quality monitoring stations operated by government entities (national, provincial and local) (DEAT, 2009a). The purpose of this survey was to assess the readiness of these stations to provide ambient air quality data to the South African Air Quality Information System (SAAQIS). The survey identified 97 stations, however, not all stations were operational. Problems cited included lack of finances and training. This lack of credible ambient data has hampered air quality management initiatives.

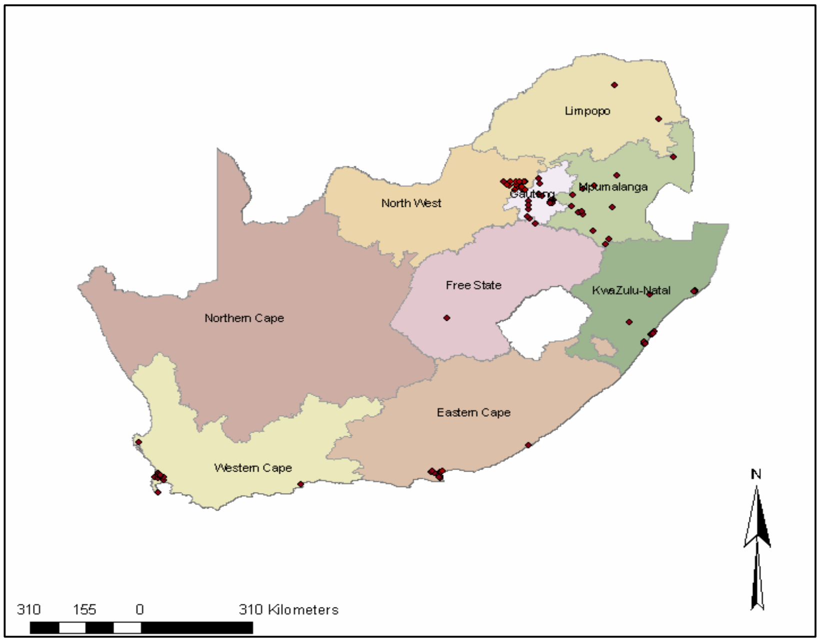

Figure 1.2 **Location of the sulphur dioxide monitoring stations in South Africa (Zunckel *et al.*, 2006b)**

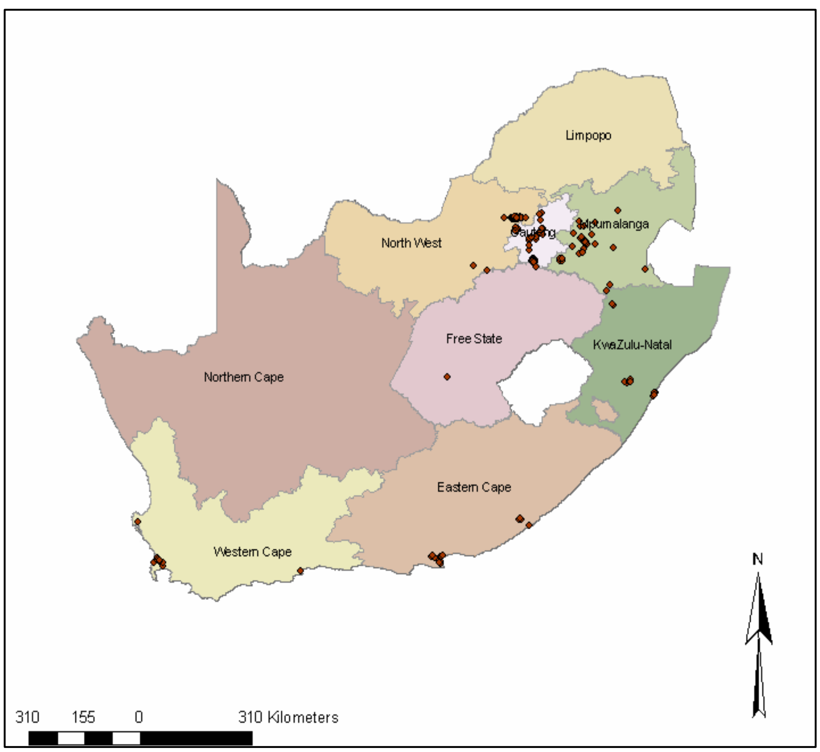

Figure 1.3 **Location of the particulate matter (PM10) monitoring stations in South Africa (Zunckel et al., 2006b)**

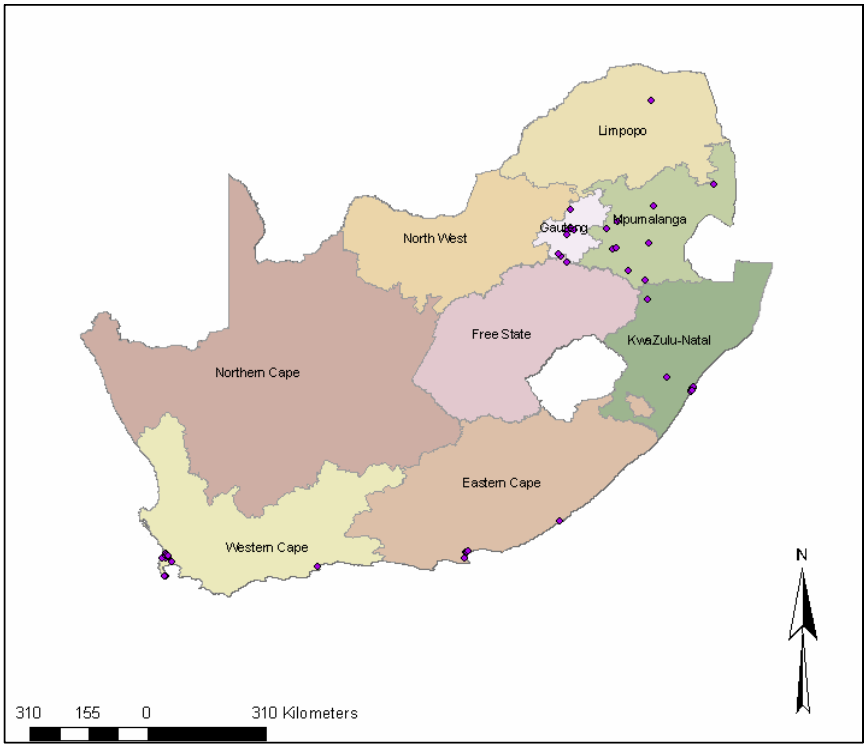

Figure 1.4 Location of the oxides of nitrogen (NO_x) monitoring stations in South Africa (Zunckel *et al.*, 2006b)

Another factor hampering air quality management initiatives is the absence of a comprehensive national emissions inventory (Scorgie *et al.*, 2004a). Until 2007 the Department of Environmental Affairs and Tourism (DEAT) (now DEA) operated regional offices, which were responsible for the registration and management of all the companies operating scheduled processes in terms of the APPA in their designated areas. In 2007, all of these regional offices were closed and their archives were centralised in the Pretoria office. For the first time in the history of the APPA a consolidated archive of all registration certificates was produced. The contents of the archive were captured in an electronic database (DEAT, 2006b). An analysis of the content of the electronic database is presented in Chapter 4. Most of the major metropolitan municipalities are in varying stages of completion of their emission inventories, however, these are independent initiatives with limited co-operation and co-ordination. This leaves the balance of the country with little to no readily available emission information.

As highlighted above, one of the largest challenges hampering the implementation of the AQA, is the lack of skilled and experienced air quality management practitioners. From 1965 until the present, air quality management in South Africa has been undertaken by a core group of national government officials. As a result, there is now a critical skills shortage as the new air quality management legislation is rolled out to the other spheres of government. There is currently no undergraduate training programme for air quality management at any of the tertiary institutions in South Africa, and limited opportunities for post-graduate study. The University of Johannesburg (UJ), in association with the National Association for Clean Air (NACA), is now offering a suite of short courses in air quality management related topics. In the interim, this skills shortage is being addressed by intergovernmental co-operation, where capacitated spheres of government are assisting the less well resourced and less prepared.

1.2 Goal

Within this context of a lack of readily available air quality management information, the goal of this research was to develop a methodology for the delineation of the boundary of an air quality management area. This methodology will then be applied in the context of South Africa's new air quality legislation, which introduces priority area management as one of the new air quality management tools.

The preliminary objective of the research was to identify the specific criteria that should be considered when developing the methodology. This was based on a review of similar international methodologies. Internationally the boundary determination process is reliant on data intensive techniques such as dispersion modelling and long term ambient air quality monitoring results (Van Aalst *et.al.*, 1998; EC, 2003; Woodfield *et al.*, 2002; Fisher *et al.*, 2005). Following the identification of these criteria the next objective was to identify or develop a proxy methodology for assessing the impact of each of these criteria. This would assist in overcoming the lack of detailed air quality management information, namely comprehensive emission inventories and long term ambient air quality monitoring data. A further objective was to combine the relevant criteria to produce a single indicator or value as to the air pollution impact potential of the area under consideration. This methodology would then be tested in the South African context. The final objective of the research was to assess the results of the application of the methodology on the regulatory framework proposed by the AQA. Here the results would be compared to the delineation of the current national priority areas, the potential for provincial priority areas would be explored and a comparison with the current Table 24 local municipalities with "poor" or "potentially poor" air quality, as specified in the National Framework. Following the identification of the boundaries of the priority areas, the necessary air quality management planning initiatives could commence. In terms of Section 15(2) of the AQA all municipalities in South Africa must prepare an air quality management plan that is included in their integrated development plan (IDP). In the case of a national priority area, the DEA will take the lead on the air quality management plan development, in collaboration with the affected provincial and local government structures. In the case of a provincial priority area, the affected province will take the lead on the air quality management plan development, in collaboration with the affected local government structures.

The principle of using readily available information will allow the application of this methodology in other developing countries. The application of this methodology must be seen as an iterative process with the more data intensive techniques replacing this methodology as the information come available in South Africa.

1.3 Structure of the Thesis

Chapter 1 of the study introduces the topic matter and sets the objectives of the research. Chapter 2 provides a background to the history of air quality management legislation in South Africa, including information regarding the forthcoming entry into effect of the AQA. Specific emphasis is placed on the provisions in the legislation relating to air quality management planning. Chapter 3 provides a review of the legislative requirements and frameworks under which applied air quality management occurs for five different international examples, with specific emphasis on the approach taken in respect of the delineation of the boundaries of air quality management zones or areas. It must be noted that all the countries selected apply a similar air quality management philosophy to that which will be applied in South Africa under the AQA, namely an effects-based approach. Chapter 4 details the methodology proposed for application in South Africa. The data that will be used in the assessment of the methodology are also described. Chapter 5 presents the results of the application of the methodology. The results from each of the criteria will be presented in addition to the consolidated results. The results will be presented at District / Metropolitan Municipality level and the Local Municipality level. Chapter 6 will contain a discussion of the results presented in Chapter 5, with specific emphasis on the implications for national, provincial and local government structures in South Africa. Chapter 7 will conclude the study with a summary of the key findings and recommendations for a way forward for the research in this field in South Africa.

CHAPTER TWO
HISTORY OF AIR QUALITY MANAGEMENT IN SOUTH AFRICA

2.1 Introduction

Air pollution is a problem affecting many parts of the world, in both developed and developing countries. Pollution sources in developed countries are typically associated with industrial pollution and emissions from motor vehicles, while pollution sources representative of developing countries are typically associated with emissions from the domestic use of low grade, low costs fuels used for space heating and cooking requirements (Emmott, 1996; Brimblecombe and Cashmore, 2002; Elsom and Longhurst, 2004; Khare and Kansal, 2004; Brimblecombe, 2005). The air pollution profile in South Africa has characteristics of both. The five main sources of air pollution in South Africa, according to Petrie *et al.* (1992) are, fuel combustion in stationary activities, fuel combustion in mobile activities, industrial and chemical processes, solid waste disposal, particularly through incineration and land surface disturbances giving rise to dust i.e. unpaved roads, agricultural emissions and other wind-blown emissions. The description provided by Petrie *et al.* (1992) is not considered complete, since it makes no specific reference to domestic fuel burning which is considered a significant source of air pollution in South Africa, especially during the winter months (Annegarn and Scorgie, 1996; Scorgie *et al.*, 2004a; Pauw *et al.*, 2008; DEA, 2009a). While it may be captured under the broad description of fuel combustion in stationary activities, the significance of this source deserves specific mention.

Management of these diverse sources of air pollution is clearly a complex task and South Africa has a relatively long history of attempting to address at least some of these sources. This chapter will explore the history of air quality legislation and management in South Africa to provide a context for the specific objectives of this research.

2.2 Early Period Prior to 1965

There was no significant industrial activity in South Africa until the end of the 19^{th} century (Brown and Brown, 1929). There was limited copper mining at O'okiep, diamond mining in Kimberley from 1870 and gold mining in the eastern Transvaal from 1872 and the Witwatersrand from 1884. The industrialisation of South Africa proceeded slowly until 1939, when the Second World War interrupted the supply of manufactured goods traditionally imported from Europe. This factor led to more local industrialisation. Rapid industrial development in South Africa in the post-World War II period increased the emissions of air pollutants into the atmosphere such that by 1955 there was cause for concern (Boegman, 1979).

Contrary to the pattern in other countries, it was not the general public who raised concern over the increasing impact of air pollution, but the local scientific community. Articles relating to air pollution by Elliston (1948, 1950) and Quass (1950, 1951 and 1953) appeared in technical journals, highlighting the deterioration in air quality in Europe and the United States, however, little or no information of this nature existed in South Africa. Halliday measured air pollution for the first time in South Africa in Pretoria in 1952 and in 1960 headed the newly formed Air Pollution Research Group of the Council for Scientific and Industrial Research (CSIR) (Boegman, 1979). In 1955 the first conference on air pollution in South Africa was convened, attended primarily by scientists and government officials. The key decision taken at this conference was the need for the drafting of air pollution control legislation (Boegman, 1979). This process culminated in the promulgation of the APPA.

2.3 Atmospheric Pollution Prevention Act

The APPA was based on old United Kingdom legislation i.e. British Alkali Act of 1865, Alkali Works Regulation Act of 1906 and the Clean Air Act of 1956 (DEAT, 2002). The legislation required the application of the "best practicable means" (BPM) to limit emissions from industrial sources, but due to its framework nature, provided very limited guidance for the practical implementation of the concept. This approach, although having some positive impacts on source-based emissions, did not effectively take into account the cumulative impacts of these and other non-point-source emissions (DEAT, 2002).

Until 1995, air pollution control vested with the Department of National Health and Population Development. As a result of a recommendation from the Council for the Environment, air pollution control was brought under the authority of the DEAT (Council for the Environment, 1994). APPA provided for the appointment of a Chief Air Pollution Control Officer (CAPCO). This was an appointment in name and was made directly by the responsible Minister. In total, there have been seven CAPCO appointments in terms of the APPA. All of these appointments have been on a national basis, with the exception of the North West Province, which had a provincial CAPCO. The CAPCO, together with the inspectors was responsible for the management and control of air pollution in four broad areas; *viz*. noxious and offensive gases, smoke, dust and motor vehicles.

2.3.1 Control of Noxious and Offensive Gases

The control of noxious and offensive gases relate to the 72 scheduled processes listed in Schedule 2 of the APPA. These include the large industrial operations in South Africa i.e. oil refineries, coal-fired power generation, iron and steel plants and numerous chemical processes. A 2006 review of the scheduled process database indicated that there were 2578 companies issued with registration certificates in South Africa (DEAT, 2006b).

A company may not operate a scheduled process without being in possession of a valid registration certificate. Applications for registration certificates are submitted to the CAPCO. The CAPCO issues a registration certificate having been satisfied that the company making application is applying BPM to prevent or reduce the escape of noxious or offensive gases. In addition, the CAPCO must take into consideration the nature and purpose of the operation, character of the locality and other relevant considerations before issuing a registration certificate. The definition of BPM relates to the use of approaches which are both technically and economically feasible (Emmott, 1996). The determination of BPM is made on a discretionary basis by the CAPCO in consultation with the relevant industry. The application of BPM leads to the determination of specific emission limits that can be applied to that operation. These emission limits are then reflected in the registration certificate and are considered guidelines that are not legally binding on the operator.

The CAPCO may issue a provisional or a final registration certificate. Provisional certificates are normally issued to new operations with specific conditions that relate to quantities of raw materials, emission limits of specific pollutants and the performance of pollution abatement equipment. Provisional certificates are issued for periods ranging from three to 60 months, and are renewable. A final registration certificate is issued subject to all the conditions in the provisional certificate being met. A final registration certificate is valid for the lifetime of the operation or until modifications are made to the plant which require amendment to the registration certificate.

2.3.2 Control of Smoke

APPA’s provisions relating to the control of smoke only apply in areas specifically designated by local authorities. Within these areas APPA provides for three levels of control.

Level 1 relates to enforcement of the provisions relating to the installation of fuel burning appliances which do not conform to certain standards and local authority approval for the siting of fuel burning appliances and chimneys. The local authority is responsible for ensuring that smoke from an approved appliance will not be prejudicial to human health or cause a nuisance. Where smoke does cause a nuisance, the local authority must serve an abatement notice on the polluter.

Level 2 applies to more significant smoke problems allowing for controls to be applied to boilers, light industries and combustion of waste. Local authorities are given power to make regulations relating to the emission of dark smoke, the installation, alteration, extension or removal of fuel burning appliances, the sale or use of solid fuel, record keeping and the inspection of polluting facilities. In the event of contravention the local authority can serve a notice requiring compliance within a specified period.

Level 3 concerns areas established by local authorities as smoke control zones, in which the emission of dark smoke may be prohibited. This level applies mostly to residential zones.

One problem with the provisions of the APPA relating to smoke control is the difficult and subjective task of determining what constitutes a nuisance. Nuisance is not defined in the Act, however, it does provide that smoke which is prejudicial to health or which adversely affects the reasonable comfort of occupiers of adjoining or nearby premises is a nuisance. A further criticism of APPA is that the provisions on smoke only apply in areas designated by local authorities. After such designation has been made, the Minister may transfer the powers of the local authority to the CAPCO in instances where the local authority fails to prevent or abate nuisances.

2.3.3 Control of Dust

APPA provides for the control of dust emitted from industrial processes not covered by other provisions of the Act. The dust control measures apply in areas designated by the Minister, who may also issue regulations concerning steps to prevent or minimise dust nuisances and inspection of premises creating dust.

Any person who operates a process that creates a dust nuisance in a dust control area must apply BPM to abate the dust. Dust emanating from depositions in excess of 20 000 cubic meters is subject to direction from the CAPCO.

As with scheduled processes and smoke, dust control is regulated without reference to legally binding air quality standards. Such standards would be useful in determining whether the dust generated by a particular operation is considered a nuisance.

2.3.4 Control of Vehicle Emissions

APPA provides for the control of vehicle emissions in local authority areas as designated by the Minister. Before this designation can be made the local authority must have access to a test centre and suitable measuring equipment. Local authorities whose areas are designated are empowered to authorise any person to detain or inspect any vehicle, to require a driver to stop while a test is carried out and to serve notices requiring vehicles to be made available for examination.

APPA allows the Minister to make regulations regarding the use of vehicles emitting specific gases and concerning the prevention or testing of emissions. To date, regulations have only applied specific emission controls to diesel driven vehicles. A shortcoming of the current regulatory regime is its reliance on the vigilance of the local authorities. At present the City of Cape Town is the only local authority in the country with a regular vehicle testing programme. In all other local authorities the testing programmes have fallen away due to diminishing human, technical and financial resources.

2.3.5 Critical Analysis of APPA and Air Quality Status in South Africa

APPA has largely been discredited as workable legislation because it is not legally enforceable, since it provides ambient air pollution guidelines instead of standards, and in many cases it has simply not been applied due to lack of capacity and/or resources. An often overlooked factor is the historically low political priority attached to air quality management in South Africa (DEAT, 2002). APPA only regulates industries on an individual basis with no consideration of cumulative or synergistic pollution impacts. Another criticism of APPA is the lack of transparency and public involvement in the determination of conditions and emission limits in registration certificates. The lack of transparency is contrary to the principles of the NEMA, as amended. APPA was regarded by many people as unconstitutional, as it did not set any targets or standards that would permit the achievement of an environment which is not harmful to health or well being in accordance with the Constitution. There was no underlying drive towards cleaner air contained in the Act. Furthermore, it was not suited to the new allocation of provincial and local government roles as specified in the Constitution, as the provinces were excluded (DEA, 2009a). Due to limited resources (human and financial) during the 1980's and 1990's many provisions of the APPA were not fully enforced, which resulted in the occurrence of a large number of industrial operations that were not registered in terms of the Act. Licencing backlogs, infrequent compliance inspections and "vague" registration certificate conditions, resulted in a situation where the industrial impact on the ambient environment was difficult to determine.

APPA also gave wide discretionary powers to the Minister and the CAPCO. The Act included numerous phrases that were prefaced with 'may' and 'might'. For example, the Minister may appoint a CAPCO. The Act also made no legal provision for any form of ambient air quality monitoring. The CAPCO may prescribe monitoring at his/her discretion. APPA prescribes a list of scheduled processes for which a registration certificate is required. The registration certificate is issued by the CAPCO. Again, there is a large amount of discretion in the application of the BPM approach by the CAPCO. APPA had a very weak penalty system for offenders. A first offence resulted in a maximum fine of R500 or a prison sentence up to 6 months, or both. A second offence incurred a maximum fine of R2000 or a prison sentence up to 1 year, or both. To date there have been few successful prosecutions in terms of the APPA (Glazewski, 2000).

Given the deficiencies of the Act and its implementation, there is also a range of specific circumstances in South Africa that result in degraded air quality. The air quality problem of greatest significance is that of domestic fuel use which results in direct exposure to elevated air pollution concentrations of especially particulates, but including sulphur dioxide (SO_2), oxides of nitrogen (NO_x) and volatile organic compounds (VOCs). The problem is dramatically compounded in the winter months by poor dispersion potential. The presence of a highly stable, stratified atmosphere, including surface inversions, traps and accumulates these pollutants close to the ground (Diab, 1975, Cosijn and Tyson, 1996). In a study conducted by Terblanche *et al.* (1992) in the Vaal Triangle, a heavily industrialised area interspersed with several dense low income settlements, it was found that internationally accepted health standards for particulate matter were exceeded by two and a half times. As a result, children living in these areas carried a risk of developing upper respiratory infections 21 – 103 % higher than children living in relatively unpolluted areas. In many respects the problem of domestic fuel use appears intractable and as such political support for efforts to resolve this problem is limited.

The next important problem is the heavy dependence on low-grade (low calorific value and high ash content) coal for electricity generation. Although, until recently, this has allowed for electricity pricing to be kept relatively cheap, deemed an important economic growth driver, emissions of SO_2 and NO_x to atmosphere from power stations were not controlled. Although the environmental effects such as acidification are not readily observed, the sheer volume of the emissions to atmosphere is a cause for concern. Additionally, the carbon dioxide emissions are not controlled either and power generation is a major source accounting for ~ 40% of the greenhouse gas emissions in South Africa (ERC, 2007). Given the recent escalations in the cost of electricity in South Africa, more is now being done to minimise energy usage and to promote its more efficient use (Eskom, 2008). Of concern is the continued reliance on coal fired power generation into the future. With the nuclear build programme delayed due to financial constraints and the lack of progress in the development of renewable energy sources, South Africa has reverted to coal fired power generation as the energy source of choice in the short to medium term.

South Africa has an ageing motor vehicle parc, with the average age of a vehicle being 11 years (Swan, 2009). The emissions from motor vehicles on South African roads are largely uncontrolled. While many new vehicles are fitted with emission control equipment (i.e. catalytic converters), the majority of vehicles are old and poorly serviced. Although lead has now been phased out of the fuels used in South Africa, the quality of the petrol and diesel, specifically the sulphur content, is still inferior to fuels produced in Europe and North America. As such, the full benefit of the emission control equipment on modern vehicles is not realised. In a response to a limited reliable public transport system the minibus taxi industry has grown exponentially over the last twenty years, but again many of the vehicles in the taxi fleet are poorly maintained. In Cape Town, the development of a thick brown haze under stable atmosphere conditions, predominantly in winter, principally owes its origin on to emissions from diesel vehicles (Wicking-Baird *et al.*, 1997).

South Africa is also prone to extensive bush or wild fires, commonly termed veld fires. These extend over large areas of the country and are a major source of low-level pollutant emissions. Paradoxically, the dry winter season (during which these veld fires occur) is also a time when the atmosphere is extremely stable further exacerbating the effects of these fires in degrading air quality. Many of these fires occur naturally due to lightening strikes, but many more are set deliberately. Fire is used as part of a grassland management programme where burning plays a key role in ecology; controlled fires are used to burn firebreaks to prevent runaway fires and damage to property, or in agriculture. Prior to sugar cane harvesting it is common practice to burn a field to remove the trash (old outer leaves of the plant) and drive pests (rodents and snakes) from the fields. Emissions from this source were intensively researched during the South African Fire-Atmosphere Research Initiative (SAFARI) in 1992 and the follow-up SAFARI 2000 field campaigns (Garstang *et al.*, 1996; Swap *et al.*, 1996; Swap *et al.*, 2002)

Poor land use planning is also a key consideration in understanding degraded air quality in South Africa. One of the most prominent examples is the South Durban Industrial Basin, where two large oil refineries together with a variety of other heavy and light industrial operations, major transport infrastructure including road, sea and air are all located in very close proximity to densely populated residential areas (Diab *et al.*, 2002; Barnett and Scott, 2007). There are several other examples of similar situations in the country including the Milnerton area in Cape Town, Richards Bay and the Vaal Triangle. Historically there has been virtually no attempt at incorporating air quality as a component of transport planning. Many of the land use planning problems currently experienced are legacy issues from the apartheid era, however more recently, the problems associated with air pollution and incompatible land use planning are pressures associated with service delivery and poor consultation during land rezoning processes.

The effects of mining have also led to many air quality problems in South Africa. One such example is windblown dust from mine dumps from gold mines. In areas of Soweto for example, residents live with the problem of ceilings collapsing under the weight of the dust, let alone the potential health effects of exposure to the same (Annegarn and Sithole, 1999). Coal mining is also a major source of dust as well as releases of methane (an important greenhouse gas). In addition, underground fires in abandoned coal mines and in some instances old stockpiles of discard coal also contribute to degraded air quality through spontaneous combustion (DEAT, 2007b). Finally, various metal refineries and smelters associated with beneficiation of the minerals generate large volumes of air pollution especially in the North West, Mpumalanga and Limpopo provinces. Under the APPA the management of air quality issues on mines was the responsibility of the Department of Minerals and Energy (DME) (now the Department of

Mineral Resources and the Department of Energy). A lack of co-operative governance led to under regulation of the environmental performance of this sector.

Having highlighted the above issues, it is still considered that the full extent of air pollution and associated impacts has not yet been researched and described for the Republic. Continuous ambient air quality measurements are currently taking place in the major metropolitan centres of the country i.e. Johannesburg, Cape Town, Durban and Pretoria. Comprehensive ambient monitoring networks have been installed at the industrial hubs of Richards Bay and the Coega Industrial Development Zone (IDZ) near Port Elizabeth. The balance of ambient air quality monitoring is undertaken by industrial entities that use the information for research and regulatory compliance purposes. There is currently no single emissions inventory for the country, with emissions information gathered for site specific investigations. The City of Cape Town is considered to have the most comprehensive emissions inventory following numerous scientific investigations and research projects that have been based in the city. The City of Johannesburg, Ethekwini Municipality (Durban) and the Buffalo City Local Municipality (East London) are currently in advanced stages of the development of their own emissions inventories. Information on air pollution sources outside of these centres is extremely limited and several attempts at establishing a national air pollution database have not reached fruition. The DEA is developing the SAAQIS whose ultimate objective is to be the national repository for all air quality information in the country (www.saaqis.org.za). Phase I of the project, the ambient air quality monitoring module, was recently completed and as at October 2009 had 52 government (national, provincial or local government) stations reporting to the national database. The objective is to expand this number to include other government and industry operated stations in the short to medium term. Phase II of the project, the emissions inventory module, is currently under development.

There have been few health studies that focus on the direct health effects of prevailing air quality, but those that have been done, for example in the South Durban Industrial Basin (eThekwini Municipality, 2006) and the Vaal Triangle (Terblanche *et.al.*,1992) highlight the potential health risks as a result of exposure to high concentrations of air pollution. More recently, air quality related issues have been taken up by civil society which has seen the mobilisation of action groups in all the major urban/industrial centres including Durban South, Milnerton, Richards Bay, Pietermaritzburg, Rustenburg and the Vaal Triangle. Pressure from these non-governmental organisations have been instrumental in the development of action plans to address the air pollution in the problem areas i.e. Multi-Point Plan for South Durban, Richards Bay Clean Air Association and the Vaal Triangle Airshed Priority Area.

Air quality management in South Africa has been undermined by a serious lack of resources, both financial and human. As indicated, Johannesburg, Cape Town, Durban and Pretoria have made sustained efforts to monitor and manage air quality. The national smoke and SO_2 monitoring campaign, which was the most ubiquitous (if limited) approach to ambient air quality monitoring, is no longer nationally administered. Most town councils and municipalities which previously monitored at least these two pollutants no longer do so. Those that continue to operate the monitoring equipment face ongoing budget constraints and it seems most likely that the network will continue to deteriorate. Many of the staff in these councils and municipalities complains of a lack of political support for ongoing air quality management (DEAT, 2009a).

2.4 The Constitution and Air Quality Management

The adoption of a democratic Constitution and Bill of Rights in 1996 made government accountable to the South African people. The Constitution sets out the legislative and executive authority of different spheres of government within a framework of cooperative governance. It states that national and provincial governments have concurrent responsibility for environmental management.

The Constitution states that South Africa is a sovereign, democratic state based on the values of human dignity, equality, non-discrimination, the rule of law and universal suffrage. In terms of environmental management it is important to recognise that sovereignty includes the ability to limit sovereign powers by entering into international agreements where the need arises.

Chapter Three of the Constitution sets out principles of cooperative government and intergovernmental relations that govern the relations between all spheres of government and all organs of the state within spheres. Amongst those important for environmental management are the obligations to preserve the peace and national unity of the Republic; secure the wellbeing of its people; provide effective, transparent, accountable and coherent government; respect the powers, functions and institutional integrity of other spheres of government; inform, consult, assist and support other government agencies; co-ordinate actions and legislation; adhere to agreements; and avoid legal proceedings against other government agencies.

Schedule 4 of the Constitution covers agriculture, cultural matters, environment, health services, housing, nature conservation, pollution control, regional planning and development, soil conservation, tourism, trade and urban and rural development.

The national executive has the power to supervise the provinces and to intervene where the provinces do not fulfil executive obligations in terms of the Constitution or legislation. In these circumstances it may issue directives or intervene to maintain national security or economic unity, maintain or establish national or minimum standards, and prevent unreasonable action by a province or action that prejudices the interests of another province or the country as a whole. In such cases, the national executive must report to the National Council of Provinces (NCOP) that has the power to review its actions.

The provincial governments have similar legislative and executive powers with respect to local authorities. Parts B of Schedule 4 and 5 set out a wide range of activities including planning and regulatory functions where local governments have responsibilities that affect the environment. As a result of their important role in implementing policy, effective environmental management at local level is essential for its success. Provincial government has an important role to play in setting provincial norms and standards and assisting local government to carry out its role effectively within the framework of this policy.

Section 146 of the Constitution addresses the question of conflicts between national and provincial legislation and establishes that national legislation prevails where legislation by individual provinces cannot effectively regulate a matter; where a matter requires uniformity across the nation; and where national legislation is necessary to maintain security or economic unity, or to protect the common market, promote economic activities across provincial boundaries, promote equity or to protect the environment. Other provisions include prevention of unreasonable action by provinces and to prevent prejudice to other parts of the country.

Section 195 (1) (e-g) states that public administration must be accountable, transparent through the provision of timely, accessible and accurate information, must respond to people's needs and must encourage public participation in environmental governance.

Various sections of the Bill of Rights as contained in the Constitution have major relevance for environmental policy. Section 24 of the Bill of Rights guarantees that the right to environmental protection for current and future generations. In terms of section 8 of the Constitution, the Bill of Rights applies to all law, and binds the legislature, executive, judiciary and all organs of state. This means that government must give effect to the rights in the exercise of environmental governance. In terms of section 24 people can take legal action to protect their environmental and other rights, even where government has no obligation in terms of any other statute to give effect to these rights. Section 24 also compels government to pass reasonable legislation to protect the environment, prevent pollution and ecological degradation, and secure sustainable development. Government must also ensure compliance with legislation.

The government of the Republic is constituted as national, provincial and local spheres of government that are distinctive, interdependent and interrelated. It is clear from the analysis of the provisions of the Constitution and Schedules 4 and 5, that in the case of numerous environment related functions, more than one sphere of government has legislative and/or executive and administrative authority, and that this authority is often exercised concurrently by different government agencies.

Legislation may impact on functional areas of competence. For instance, in terms of the Constitution, air pollution is an area of national, provincial and local government competence, but the APPA assigns the control of noxious and offensive emissions and dust control to national government, while assigning the control of smoke pollution and vehicular emissions to local authorities.

2.5 Environmental Law Reform and Air Quality Management

Since 1992, the DEAT acknowledged that pollution and waste management governance was inadequate in dealing with South Africa's changing social and industrial context. DEAT initiated a policy development process known as the Integrated Pollution Control (IPC) process. This process drew many concerns from civil society and was subsequently abandoned. A new process, known as the Consultative National Environmental Policy Process (CONNEPP) was initiated in 1995. This process was tasked with the development of an overarching environmental policy for South Africa.

The drafting of the Constitution of South Africa (No. 108 of 1996) allocated national, provincial and local authority responsibilities for environmental management. The Constitution also set out the legislative and executive authority of the different spheres of government within a framework of cooperative governance. It highlighted the concurrent responsibility of national, provincial and local authorities for environmental management, something which had been missing from previous legislation.

CONNEPP culminated in 1997 with the publication of the White Paper on Environmental Management Policy (DEAT, 1997). This document provided the government's national policy on environmental management, setting out the vision, principles, strategic goals and objectives. In order to give effect to the National Environmental Policy, the NEMA was promulgated. NEMA was seen as over-arching framework legislation for all the subsequent environmental legislation that has been promulgated in the recent past.

In 2000, the publication of the DEAT's White Paper on Integrated Pollution and Waste Management (IP&WM) (DEAT, 2000) for South Africa, marked a turning point for pollution and waste governance in South Africa. One of the fundamental approaches of this policy is to prevent pollution, minimise waste and to control and remediate impacts. The IP&WM policy identified a number of substantive issues relevant to air pollution which required consideration in relation to policy implementation. These include smoke (particulates) arising from coal and fuel burning, vehicle emissions, emissions from industrial activities, dust arising from mining and industrial activities, various sources of greenhouse gases, waste disposal sites, incinerator emissions, acid rain and noise. The policy conceded that the current approach to air quality management was fragmented and uncoordinated with insufficient resources to implement, monitor and enforce the current legislation. From an air quality perspective, the policy required a complete revision of the air quality legislation due to the paradigm shift from the APPA approach to the air quality management approach.

2.6 National Environmental Management: Air Quality Act

2.6.1 Introduction

In response to the IP&WM policy, DEAT drafted a new strategy for air quality management in South Africa in the form of a National Air Quality Management Programme (NAQMP) (DEAT, 2002). This strategy fulfils the IP&WM requirements for the development of detailed strategies for pollution and waste management. The strategy provides details on how the government intends to roll out the NAQMP in the form of a detailed analysis of objectives, outputs, activities and inputs for the key components of the programme.

The drafting of new air quality legislation was one of the initial goals of the NAQMP. This process culminated with the promulgation of the AQA in February 2005. The introduction of new air quality legislation in South Africa will see air pollution managed in a more holistic and integrated manner with the devolution of powers down to the local municipal level and the introduction of priority areas that will concentrate on "hotspots". The focus will shift towards managing air quality based on ambient concentrations with the introduction of ambient air quality standards. Ambient air quality standards have been prepared and these are based primarily on health related criteria, using the best available international research and information. Global issues such as climate change and greenhouse gas emission also receive attention in the new legislation.

Equally important is the framework legislation provided by the NEMA, within which the AQA resides, providing government with the regulatory tools to implement NEMA policy in the field of air quality. The AQA is one of the pieces of legislation in a suite of laws framed within NEMA. Other legislation under NEMA includes the National Water Act (No. 36 of 1998), National Environmental Management: Protected Areas Act (No. 57 of 2003), National Environmental Management: Biodiversity Act (No. 10 of 2004), National Environmental Management: Integrated Coastal Management Act (No. 24 of 2008) and National Environmental Management: Waste Act (No 59 of 2008).

2.6.2 Passage of the Air Quality Bill

The process leading up to the promulgation of the Act was rather protracted and at times difficult. The Bill was initially issued for public comment on 1 April 2003, whereafter a number of submissions were made to the DEAT by a wide range of stakeholders. In total 240 comments were received from 23 different organisations (DEAT, 2004). The submissions covered a wide range of topics, namely, points of clarity, provisions for appeals, changing voluntary obligations to compulsory obligations (changing may to must), provisions for exemption and revisions to specified timeframes (DEAT, 2004). In response to these submissions the Bill was revised and then submitted to the NCOP for consideration on 1 October 2003. A Select Committee reviewed the document and made recommendations for limited changes to the Bill. The Bill was then passed to the National Assembly for consideration. The Parliamentary Portfolio Committee for Environmental Affairs and Tourism held public hearings on 3 and 4 February 2004. Stakeholders ranging from industry to Non Government Organisations (NGOs) and Community Based Organisations (CBOs) made presentations and submissions to the Committee (DEAT, 2004). Based on the concerns and issues raised during these hearings, the Bill was withdrawn for further revision. The Bill was re-introduced following the General Elections in April 2004. The amended Bill was debated in the National Assembly on 25 August 2004 and passed. Following approval from the NCOP the Bill was signed by the President on 19 February 2005.

2.6.3 Critical Analysis of AQA

A critical feature of the AQA is that it is consistent with our constitutional right to an environment that is not harmful to our health or well-being. In earlier drafts of the Bill, this emphasis on the protection of human health and the environment was not explicit, but through concerted lobbying by stakeholders, the object of the legislation was revised to its current form.

APPA has been criticized for its lack of transparency. The BPM approach allowed officials and industry to decide on an emissions target on the basis of a non-transparent process of negotiation. Under the AQA, legislated ambient air quality and emissions standards must be established and applied nationally. The AQA makes provision for setting of provincial and local emission standards, on condition that the standards are stricter than the national standards. The process of establishing national standards and any subsequent provincial and local standards is clearly specified, with the public consultation and participation processes integral to the process.

A list of offences is given in Chapter 7 of the AQA. These include conducting a listed activity without a license or contravening the conditions of a license, as well as failing to submit relevant reports, such as a pollution prevention plan or an atmospheric impact report. The provision of false information during the licensing process is also regarded as an offence. In contrast to the APPA, offences are now explicitly stated and hence are more likely to lead to prosecutions than under the APPA. Few prosecutions by the state under the APPA were successful. Enforcement is expected to improve as it will involve all spheres of government, including provincial and local government. All spheres of government are empowered to issue fines to offenders.

Table 2.1: Summary of the Differences between APPA and AQA

APPA	AQA
Source-based emission control	Combination of ambient air quality management approach and source-based control
Source-based approach using BPM	Effects-based approach using Air Quality Management (AQM)
Four categories of control - noxious or offensive gases - dust - smoke - vehicle emissions	Potentially covers all pollutants identified by the Minister, including odour and noise
No legal requirement for ambient air quality monitoring	Requires municipalities and provinces to undertake ambient air quality monitoring
Identifies scheduled processes	Identifies listed activities
Required to appoint a National Air Pollution Advisory Committee (NAPAC) but may appoint a CAPCO	May appoint a National Air Quality Advisory Committee (NAQAC) but must appoint a national, provincial and local air quality officer
Weak penalty system for offenders	Stricter penalty system of fines and prison sentences
Does not protect public health or the environment	Upholds the constitutional right to a safe and healthy environment
Does not address trans-boundary and international issues / obligations	Addresses trans-boundary and international issues / obligations
Lacking in transparency and accountability	Includes a provision for co-operative governance
Makes no provision for solving problems in hotspot areas	Requires preparation of an Air Quality Management Plan (AQMP) to address air quality issues in a particular area
Issuing of permits based on non-transparent negotiation between government and industry	Requires industry to make public their application for a license

A key issue to be addressed in improving air quality management in South Africa is effective coordination between a variety of different government departments. For example, the Department of Minerals and Energy has an active interest in motor vehicle emissions and air pollution from domestic fuel use, the Department of Health (once the implementing agency for APPA) has an interest in the public health aspects or air pollution, the Department of Transport can have a huge bearing through suitable transport planning and so forth. Coordination between these departments will be crucial in ensuring that there is no duplication or that issues are not effectively addressed because there is little or no buy-in from the necessary state department. Progress has already been made with the formation of the Intergovernmental Task Team between the Departments of Energy, Transport and Environmental Affairs to formulate and co-ordinate regulatory controls for motor vehicles.

The AQA is generally considered to be framework legislation, and as such, provision was made under section 7 of the Act for the development of a National Framework. The National Framework for Air Quality Management in South Africa was gazetted on 11 September 2007 and provided detailed guidance on the implementation of the AQA (DEAT, 2007a). The National Framework expanded on the methodology to be followed during the development of the air quality management tools for the efficient and effective implementation of the AQA. During the drafting of the 2007 National Framework a number of the transitional projects undertaken in preparation for the transition to the AQA had not yet been completed. Section 7.1 of the National Framework indicated that the 2007 version was considered a 1st Generation draft and this would be followed by a more complete document (2nd Generation) by September 2008. The DEA has decided to postpone the revision of the National Framework, in order to include additional regulatory information i.e. guidance on atmospheric dispersion modelling.

The National Framework specifies that the repeal of the APPA and full entry into effect of the AQA will take place in the 2009/10 financial year (DEAT, 2007a). The DEA initially indicated that 11 September 2009 was an internal target date for the transition, however this date was not achieved due to internal delays relating to restructuring following the 2009 General Elections. The revised target date for the transition was 1 April 2010. This allowed sufficient time for finalisation of all the necessary regulations, templates and guidance documents. Critical path items outstanding as at 1 December 2009 were the ambient air quality standards as required in terms of Section 9 of AQA, the listed activities and associated minimum emission standards as required in terms of Section 21 of the AQA and the licencing templates required in terms of Section 37 of the AQA. This delay also allowed additional capacity building and skills development opportunities with the provincial and local government authorities.

CHAPTER 3
REVIEW OF INTERNATIONAL APPROACHES TO AIR QUALITY MANAGEMENT

3.1 Introduction

This chapter provides a review of the legislative requirements and the frameworks under which air quality management for five different international examples are applied, with specific emphasis on how these systems manage areas with ambient air quality concentrations in excess of local standards or limit values. Particular attention is paid to the methodology used to define or delineate the boundary of the air quality management areas, zones or regions. The chapter first examines the European Union's (EU) approach to air quality management and notes that the EU does not define a specific methodology for the identification of air quality management zones within Member States. However, general guidance is provided to ensure a degree of consistency across the Union. Secondly, a detailed analysis on the definition of boundaries of air quality management areas in the United Kingdom (UK) is given, followed by the United States' approach under the Clean Air Act. The division of powers between the federal government and the states is described, again with specific emphasis on how the air quality management planning systems identify areas that do not comply with the National Ambient Air Quality Standards (NAAQS). The Australian approach to air quality management is reviewed, with emphasis on how the National Environmental Protection Measures (NEPMs) have been used together with population density, detailed emission inventories, topography and atmospheric dispersion potential in the identification of regional and local airsheds. Finally, an analysis of New Zealand's approach to air quality management planning under the Resource Management Act is undertaken, with specific reference to the identification of local air management areas (LAMAs).

3.2 European Union

The European Economic Community (EEC) formed in 1956 and did not begin to take specific actions with respect to environmental protection until the 1980s when the scope of pollution-related damages to Europe's forests and other ecosystems began to be recognized. In fact the EU did not get a constitutional basis for acts with respect to environmental protection until the 1987 Single European Act (Goldenman and Levina, 2004). In the meantime, a number of Member States had already developed air quality management initiatives. Part of the challenge for the EU has therefore been to harmonize not only air quality standards, but also the national systems in place for assessing and monitoring air quality (Elsom, 1999). Figure 3.1 shows the timeline of EEC / EU directives associated with air quality management.

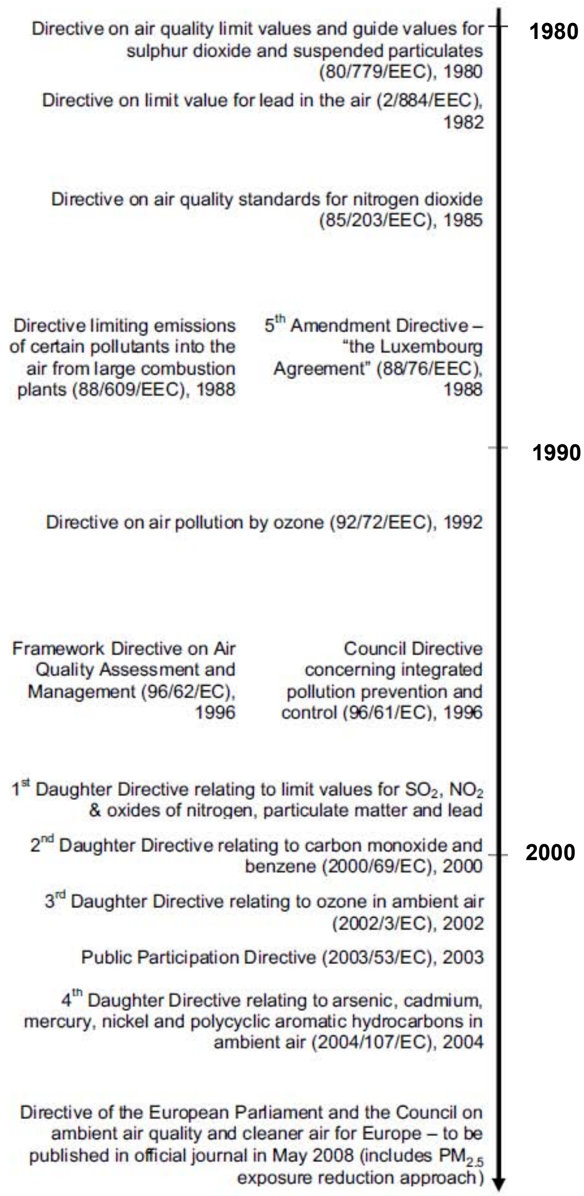

Figure 3.1 Timeline for the adoption of EU Directives to address air pollution (after Longhurst *et al.*, 2009)

As at November 2009 the EU currently comprises 27 Member States, including amongst others, the UK, Germany, France, Spain and Italy. Whilst the major objectives of the organisation are economic and political regional co-operation, environmental action has been motivated to come under this overall theme (Elsom, 1992; Jacobson, 2002; EEA, 2004). Using directives, regulations and decisions, the EU promotes environmental concern among Member States. Directives are binding, although they include consideration for conditions in individual states, while regulations apply uniformly across nations and decisions are directed at specific Member States. The 1996 Air Quality Framework Directive (AQFD) and its Daughter Directives were aimed at establishing a harmonized structure for assessing and managing air quality throughout the EU. This approach saw a shift from the "command and control" approach to air quality management to an approach that managed air pollution through ambient standards (Longhurst *et al.*, 2009). This is the approach to air quality management that has been adopted by the new South African air quality legislation.

The AQFD had four overarching objectives, the first of which was to define and establish objectives for ambient air pollution that was protective of human health and the environment; secondly, it sought to provide a standardized methodology for the assessment of ambient air quality in Member States; thirdly, to allow for the public dissemination of the ambient air pollution information gathered; and finally, to maintain ambient air quality where it is considered good and realize an improvement in areas where it is considered poor.

In addition to each Member State's obligation to address air quality management, they are required to comply with Directives in other environmental sectors, including waste management, water quality and nature conservation. There are three types of plans found in EU air quality legislation; firstly, plans to achieve specific air quality objectives; secondly, short-term plans to address urgent air quality exceedences; and thirdly, plans to reduce emissions from sources.

Within this structure, the EU Member States are given considerable scope to determine what actions they will take in order to meet their commitment to achieve the air quality objectives within their territories. However, the Member States must at the same time implement the other EU-level measures that comprise the overall EU air quality management system. These include controls over stationary sources of polluting emissions to air, such as large combustion plants, industrial installations, and facilities using solvents. Other EU-level measures aim to reduce emissions from mobile sources, such as road traffic, and include technical requirements to limit air emissions from various types of motor vehicles as well as fuel quality standards (Fenger, 2002). Finally, the National Emission Ceilings (NEC) Directive (2001/81/EC) establishes national emissions ceilings for sulphur dioxide (SO_2), oxides of nitrogen (NO_x), volatile organic compounds (VOCs) and ammonia (NH_3) (EC, 2001).

The Framework Directive requires that all Member States divide their territories into zones and agglomerations. Agglomerations are special zones that are defined as having greater than 250 000 inhabitants. The concept of a zone enables Member States to sub-divide their territories into basic areas for air quality management (EC, 1996). The Framework Directive does not prescribe a specific methodology to be used but guidance documents were drafted to assist in the designation of zones (Van Aalst *et al.*, 1998; EC, 2003). One of the stated goals of the Framework Directive was to allow for direct comparability between the Member States; as such there is great benefit in applying a consistent approach. It has been recommended that approaches considered in other Member States should be taken into account and reasons for major deviations from the general trend should be carefully considered before making a final decision.

The zones are determined based on the ambient air pollution concentrations determined at various sites within the Member States. The nature of the assessment requirements depend on the observed ambient concentrations in relation to the limit and threshold values. Each of the Daughter Directives specifies a limit value and two threshold values for each pollutant. The upper assessment threshold (UAT) and the lower assessment threshold (LAT) are both lower than the limit value and are defined as percentages of the limit value. Figure 3.2 shows the implications of exceedence of the limit value, UAT and LAT in terms of the assessment requirements.

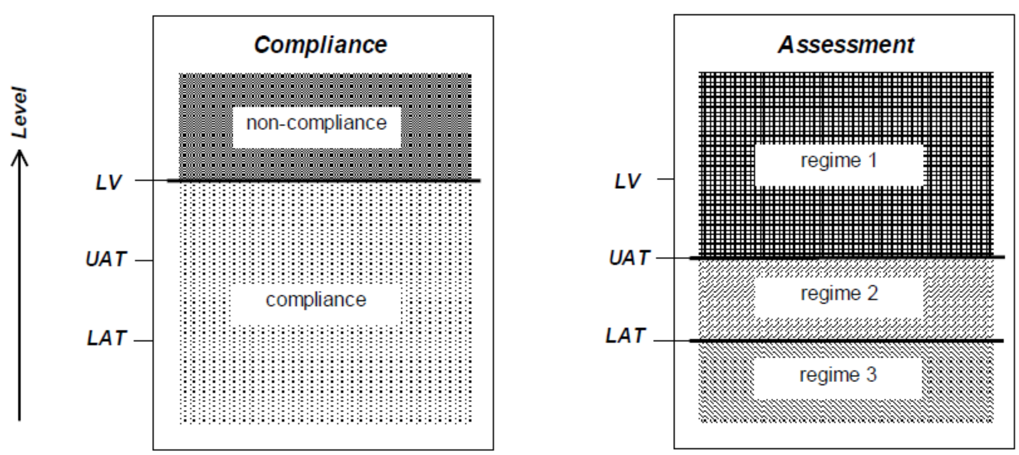

Figure 3.2 Implications of exceedence of the limit value, UAT, LAT for compliance judgment and assessment requirements in a zone (EC, 2003)

Any ambient concentration above the limit value is considered to be in non-compliance, subject to the specific attainment date for that specific pollutant. Zones with ambient concentrations in excess of the UAT trigger the assessment requirements of Regime 1 (Area of Poor Air Quality). These include mandatory high quality ambient air quality monitoring, which may be supplemented by information from other sources including air dispersion modeling. Zones with ambient concentrations in excess of the LAT but below the UAT trigger the assessment requirements of Regime 2 (Area of Improving Air Quality). These include mandatory ambient air quality monitoring but at fewer sources than Regime 1. Less intensive ambient monitoring techniques, namely passive sampling, may be used. Zones with ambient concentrations below the LAT trigger the assessment requirements of Regime 3 (Area of Good Air Quality). Regime 3 is divided into two separate categories, agglomeration and non-agglomeration zones. In agglomeration zones at least one ambient monitoring site is required and this can be supplemented with dispersion modeling, objective estimation and indicative measurements. In non-agglomeration zones dispersion modeling, objective estimation and indicative measurements alone are considered sufficient (EC, 1996).

Figure 3.3 shows a schematic diagram of how the level of air quality management in each zone is determined based on the measured ambient concentrations in relation to the limit value and the margin of tolerance.

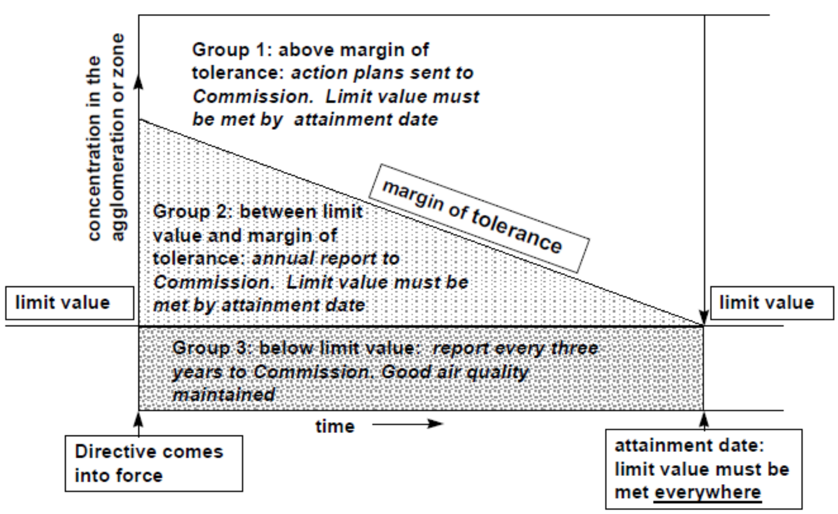

Figure 3.3 Schematic diagram used to determine zone allocation (EC, 2003)

If an area falls into Group 1, where the ambient air pollution concentrations are in excess of the limit value and the margin of tolerance, then this zone is deemed to have the worst air quality.

This triggers the preparation of a detailed action plan for the area, demonstrating how the Member State will achieve the limit value by the designated attainment date. If an area falls into Group 2, where the ambient air pollution concentrations are in excess of the limit value but below the margin of tolerance, then this zone is not required to prepare an action plan, but must report ambient air pollution concentrations to the Commission on an annual basis and also indicate any necessary steps to achieve the limit value by the attainment date. If an area falls into Group 3, where the ambient air pollution concentrations are below the limit value, then this zone is only required to report ambient air pollution concentrations every three years.

The European Commission (EC) (2003) documented and recommended the following zone designation process. The process commences with a preliminary assessment of how air quality is spatially distributed in the territory of the country or region that is responsible for the designation of zones. This focuses on the pollutants addressed by the first Daughter Directive, but it is also considers the pollutants of subsequent Daughter Directives, as far as possible. In the preliminary assessment, all relevant air quality parameters (annual averages, exceedences of hourly/daily values) are taken into account. Then an attempt is made to identify areas of similar air quality characteristics, in terms of exceedences, source types, climatology and topography. The results of the preliminary assessment are then overlaid onto a map of territories of local administrations with competence regarding the control of sources. The borders of the administrative territories are then proposed as the possible delineations of zones. Where possible, it is recommended that administrative territories with similar air quality characteristics are combined into larger areas. It is, however, important to note that zones should primarily be regarded as administrative entities for which the Framework Directive defines specific assessment, reporting and management requirements (EC, 2003).

The EC (2003) recommended that the following general principles should be taken into account when undertaking the zone designation process to ensure transparency. The use of existing administrative boundaries (cities, provinces and municipalities) was encouraged to allow citizens to clearly identify the zoning of a particular location. The borders of zones should be fixed in time, except for formal amendments that may occur from time to time. The EC (2003) cautioned against the use of spatial statistics, namely population density, as this criterion may be undefined for individual locations and changes continuously over time.

The EC recommended the following considerations be taken into account in the definition of zones (EC, 2003). As highlighted above, the importance of linking zone boundaries to administrative areas is reemphasized. The grouping of adjacent administrative areas with similar air quality characteristics is recommended. It is not recommended to group a spatially separated agglomeration with surrounding areas. The EC recommends that Member States have a clear and consistent definition of what comprises an agglomeration. The guidance provided indicates that built-up areas, not separated by more than a few kilometers, with a population in excess of 250 000 people, constitutes an agglomeration. Further guidance is provided to recommend that the agglomeration does not include significant areas that are not built-up. For the sake of consistency in reporting to the European Parliament and the EC, it is recommended that Member States or authorities within the countries do not deviate from the mainstream approaches used by the majority. This has the potential to create discrepancies within Member States and create public confusion. The use of highways as the boundaries of zones is discouraged, due to the high variability in the air pollution impact of this particular source. The administrative capacity and the legislative mandate of the sphere of administration must be taken into consideration when defining the boundaries of the zone. Overly small zones may result in an unacceptable administrative burden in some areas, while overly large zones may require co-operation and co-ordination between different spheres of government with different administrative mandates. The EC also recommended against the designation of a zone around a single industrial operation, unless this would facilitate air quality management.

While it not possible to detail the approach to the identification of zones in each Member State of the EU, a detailed review of the process followed by the United Kingdom authorities is provided in Section 3.3.

Table 3.1 provides a summary of the number of zones declared by each of the EU Member States based on their 2005, 2006 and 2007 submissions to the European Commission under the Framework Directive and the First, Second, Third and Fourth Daughter Directives. A significant difference between the three years is the inclusion of reporting from two new Member States (Bulgeria and Romania) in 2006 and the voluntary reporting of pollutants under the Fourth Daughter Directive in 2007. Further discussion is provided below.

Table 3.1: Summary of the number of air quality management zones declared by the EU Member States (Vixseboxse and De Leeuw, 2007, 2008; De Leeuw and Vixseboxse, 2008)

Member State	2005 Zones	2006 Zones	2007 Zones
Austria	19	19	19
Belgium	17	17	18
Bulgeria	Not part of EU	6	6
Cyprus	1	1	1
Czech Republic	15	15	15
Denmark	10	10	3
Estonia	4	4	4
Finland	18	18	18
France	87	88	81
Germany	140	120	120
Greece	4	4	4
Hungary	11	11	11
Ireland	4	4	4
Italy	144	121	115
Latvia	2	2	2
Lithuania	3	3	3
Luxembourg	No submission	3	No submission
Malta	2	2	2
Netherlands	9	9	No submission
Poland	362	362	186
Portugal	26	26	27
Romania	Not part of EU	4	21
Slovakia	10	10	11
Slovenia	9	9	9
Spain	140	138	138
Sweden	6	6	6
United Kingdom	43	44	44
Total No. of Zones	1064	1056	868

An analysis of the information presented in the 2007 report (De Leeuw and Vixseboxse, 2008) indicates that the area of the zones varies from 0.8 km^2 to 338 145 km^2 and that the population within the zones varies from 3 000 to 9 833 408. The zones have been sub-divided according to the pollutant specified in the First, Second and Third Daughter Directives. A total of 752 zones have been identified due to SO_2, 783 zones for nitrogen dioxide (NO_2), 770 zones for PM_{10}, 636 zones for lead (Pb), 674 zones for benzene (C_6H_6), 705 zones for carbon monoxide (CO) and 550 zones for ozone (O_3). In the EU27[1] Member States about 25-30% of the zones have been given the status of agglomeration zones which has implications for the number of required monitoring stations, since continuous ambient air quality monitoring is required in these areas. The ratio of the number of agglomerations to the total number of zones varies strongly between

[1] The 27 EU Member States after accession of 12 new Member States in 2004 and 2007

the Member States: less than 10% of the zones are classified as agglomeration zones in Cyprus, Finland, Hungary and Poland; in Bulgaria, Denmark, United Kingdom and Lithuania more than 60 % are classified as agglomeration zones. Excluding Cyprus which has not defined an agglomeration but only one zone covering the whole country and Bulgaria which has designated all zones as agglomeration, the percentage of national population living in agglomerations varies between 12% (Slovakia) and 68% (Malta). On average about one third of the EU27 population reside in agglomerations (De Leeuw and Vixseboxse, 2008).

In 2006 there were 4 386 ambient monitoring stations reporting to the European Environment Agency's European Topic Centre on Air and Climate Change (EEA/ETC-ACC) (Vixseboxse and De Leeuw, 2008). This comprised 3 020 NO_2 analysers, 2 456 PM_{10} analysers, 2 324 SO_2 analyers and 1 886 O_3 analysers.

3.3 United Kingdom

The UK has a long history in dealing with air pollution issues, dating back to the 17th Century (Evelyn, 1661). The first attempt to legally regulate air pollution from industrial sources was through the creation of the Alkali Inspectorate under the 1863 Alkali Act. This was followed in 1906 with the Alkali Works Regulation Act. This Act sought to regulate the emission of noxious and offensive gases from common industrial processes, namely chemical industries, petroleum refineries, petrochemical industries, electricity generation, coal carbonization, iron and steel works, non-ferrous metals and mineral processing works (HM Government, 1906). This legislation formed the basis of the APPA, which was the first air quality legislation in South Africa.

Figure 3.4 shows the progression of air quality legislation in the UK during the 20th Century, commencing with the Alkali Works Regulation Act in 1906 and culminating with the Environment Act of 1995. The London smogs experienced in the early 1950s saw a renewed momentum in air quality legislation in the UK, which ultimately led to the promulgation of the Clean Air Act in 1956. This saw the first introduction of emission limits and other pollution control requirements via the application of BPM (Ireland *et al.*, 1979). In the ensuing years there were reductions in the industrial and domestic emissions, primarily due to the introduction of smokeless zones in the major urban centres (Walton *et.al.*, 2001; Longhurst *et.al.*, 2009). The process of fuel switching, away from coal to gas, and the wider use of electricity in industrial processes, combined with enterprise relocations, were the major drivers in the improvement in ambient air quality conditions.

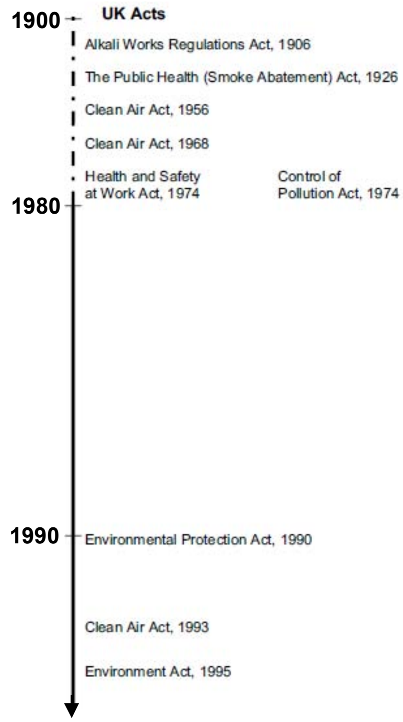

Figure 3.4 Timeline of the adoption of UK Acts to address air pollution (after Longhurst *et al.*, 2009)

As highlighted in Section 3.2, the 1980s saw the growth of the awareness of environmental issues, including air quality, in the EC. As a Member State of the EC, the UK began to adopt and implement provisions of the Directives relating to ambient air quality standards (EEC, 1980; 1982; 1985). The European Council Directive 96/62/EC on Ambient Air Quality Assessment and Management, commonly referred to as the Framework Directive, was introduced in 1996 (EC, 1996).

During the 1990s air quality re-emerged as an important environmental policy issue in the UK (Walton *et al.*, 2001). In 1990, the UK Government published its environmental strategy in a White Paper entitled “This Common Inheritance” (HM Government, 1990). This saw a move away from an emissions-based policy to an effects-based policy, primarily due to growing public concern over health effects relating to air pollution (Longhurst *et al.*, 2009). The Expert Panel on Air Quality Standards (EPAQS) was established and tasked with the development of ambient air quality standards for the UK based on the best available epidemiological information. The ambient standards produced by the EPAQS were the cornerstone of a new risk-based approach to air quality management in the UK. The 1995 Environment Act saw the introduction of a new framework termed Local Air Quality Management (LAQM), which combined the new ambient standards with the existing technology based control of air pollution.

This new approach to air quality management saw the delegation of the air pollution control and management to local government, while national government retained the policy and co-ordination function. This delegation of the air quality management function to the lowest sphere of government is the same operational philosophy envisaged in the new South African air quality legislation. The UK has over 10 years of operational experience of this model that could provide useful guidance for South Africa.

Section 80 of the 1995 Environment Act requires the Secretary of State to publish a National Air Quality Strategy (NAQS) as soon as possible. The NAQS was first published in 1997 (DoE, 1997) and then reviewed, updated and amended in 2000 (DETR, 2000) and 2007 (Defra, 2007). The focus of the NAQS was the establishment of health-based ambient air quality standards for eight pollutants, namely C_6H_6, CO, Pb, NO_2, O_3, PM_{10}, SO_2 and 1,3-butadiene (C_4H_6) (Beattie *et.al.*, 2001). Section 83 of the 1995 Environment Act requires a local authority, for any area where the ambient air quality standards are not being met, to issue an order designating an air quality management area (AQMA) (HM Government, 1995). With the publication of the NAQS in December 1997, the local authorities were legally obliged to start the process of designating AQMAs. Figure 3.5 details the assessment procedure followed by local authorities in terms of the NAQS.

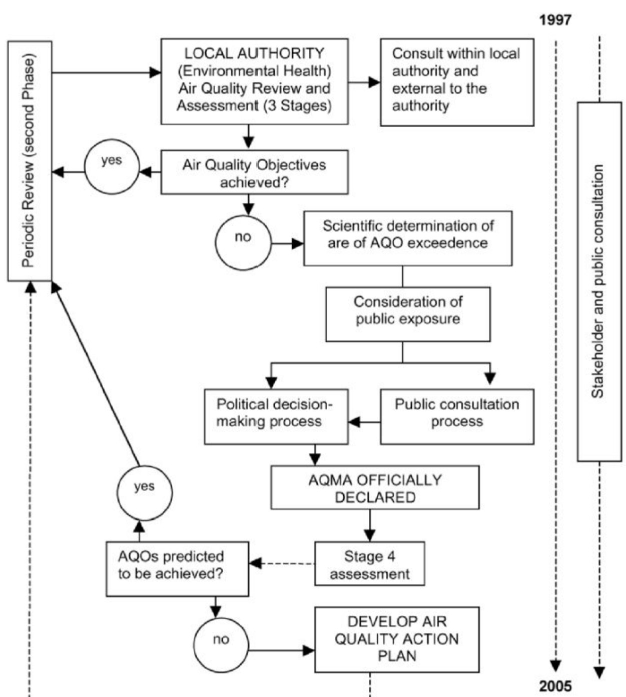

Figure 3.5 Schematic illustration of the implementation of the NAQS by local authorities (Woodfield *et al.*, 2003)

In terms of Figure 3.5 the local authorities are required to carry out a process termed Review and Assessment. The process requires the local authority to define the current and future state of local air quality. The work is considered to be continuous by the UK Government, however, the process has been broken down into distinct phases of work, referred to as Rounds. The Government plays an oversight role to ensure that the work undertaken by the local authorities is being conducted in an appropriate manner (Longhurst *et al.*, 2009). The First Round of Review and Assessment commenced in 1998 and concluded in 2001. During this time 129 local authorities declared one or more AQMAs. The Second Round commenced in 2003 and the Third Round commenced in 2006. Figure 3.6 shows the progressive number of AQMAs declared in the UK in the period 1997 – 2007. In December 2008 the total number of AQMAs in the UK was 294 (Vaughan, 2009). Figure 3.7 shows the distribution of these AQMAs in the UK.

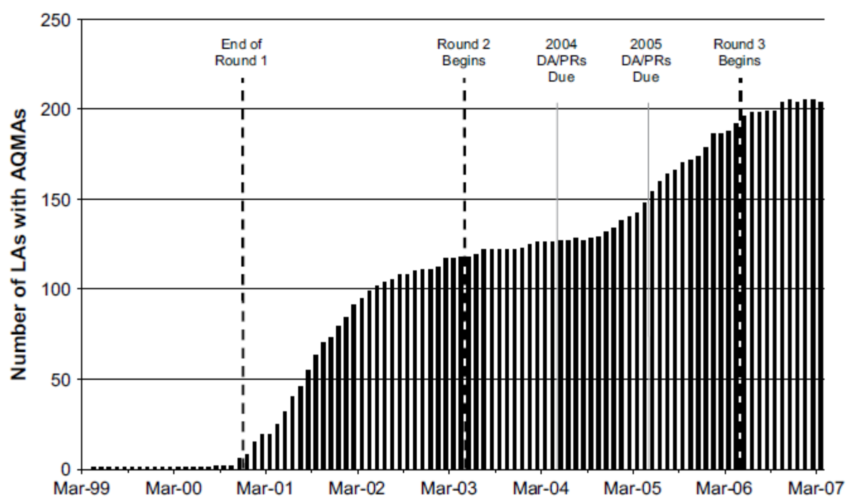

Figure 3.6 Number of local authorities with AQMAs during the period March 1999 – 2007 (Longhurst *et al.*, 2009)

Beattie *et al.* (2000) identified the need for sound science to underpin the AQMA designation process, to ensure that the process achieved its ultimate objective of achieving the UK ambient air quality standards in all areas. The National Society for Clean Air and Environmental Protection (NSCA) (now Environmental Protection UK) published a toolkit for local authorities to assist them in the definition and declaration of AQMAs (NSCA, 2000). The document acknowledged the challenge facing the local authority in defining the geographical boundary of the AQMA. It also highlighted the importance of communication and consultation with all stakeholders during the process. The toolkit provides guidance on the assessment of uncertainty from outputs of dispersion models and the validation of the modeled results against observed ambient air quality data.

A study undertaken by Woodfield *et al.* (2002) highlighted that the process of determining AQMA boundaries in the UK had emerged as highly variable. In addition the methodologies employed by the local authorities to determine the boundary of the AQMA were also highly variable. The results of the study indicated that most AQMAs were based on the outputs of dispersion modeling studies, with very few local authorities using actual observed ambient air quality data. The modeling techniques and the consideration of uncertainty varied considerably between local authorities. Due to the uncertainty of the results, many local authorities applied the precautionary principle and declared a larger area than indicated by the modeled results or alternatively declared the entire local authority as an AQMA, thereby reducing the potential risk of failing to identify any location of public exposure to predicted ambient air quality standard exceedences (Woodfield *et al.*, 2002). The methods used by local authorities for determining the exact boundary on an AQMA varied considerably. Some chose to use administrative boundaries, others chose physical boundaries such as roads, rivers and railway lines (Woodfield *et al.*, 2002). Various other local factors were identified as influencing the determination of the boundary of the AQMA. These included the local authority political regime (perceived blight factor) and factors that may impact on the overall effectiveness of an Action Plan to improve local air quality (Beattie *et al.*, 2000).

There appears to be some confusion when comparing the number of AQMAs declared in the UK at the end of 2007 (294) in terms of the UK's Local Air Quality Management (LAQM) process, with the number of air quality management zones reported to the EC in terms of the Framework Directive (44) for the same period. It must be noted that the LAQM process is UK specific and arises from the national requirements required in terms of the Environment Act. While the air quality regulations issued in terms of the LAQM process are aligned to the requirements of the EC Daughter Directive requirements, the LAQM process is not the delivery vehicle for achieving compliance with the EC Framework Directive requirements.

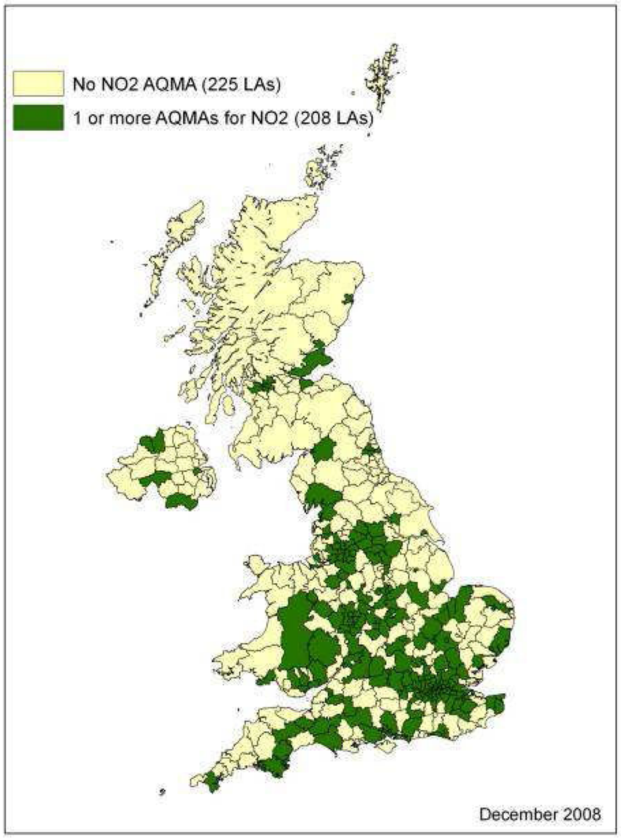

Figure 3.7 Location of local authorities with AQMAs – December 2008 (Vaughan, 2009)

3.4 United States

The Air Pollution Control Act of 1955 was the first federal air pollution law in the United States (US). Before its enactment, there were several state and local pieces of legislation addressing air pollution, but due to increasing awareness regarding the negative impacts of air pollution on public health, ecosystems and the economy, the US government decided that air pollution should be managed on a national basis (NRC, 2004). The main purpose of this initial Act was to provide research and technical assistance to enable the control of air pollution at its source, but it did little to prevent or reduce air pollution. These initial efforts were enhanced over the next 15 years through the enactment of additional air quality legislation. This included the Clean Air Act (CAA) of 1963 and the Air Quality Act of 1967. The creation of the US Environmental Protection Agency (US-EPA) and the passage of CAA amendments in 1970 helped to establish the basic framework by which air quality is managed in the US. This framework was further developed and refined with the passage of further amendments to the CAA in 1977 and 1990 (NRC, 2004). As the impacts from air pollution have become more evident, the legislation has become increasingly complex and ambitious (NRC, 2004).

The CAA prescribed a complicated set of responsibilities and relationships between the federal (national), state (provincial), tribal and local agencies. The US-EPA co-ordinates the federal government's efforts and is responsible for the development of national ambient air quality standards (NAAQS), in addition to co-ordinating the national approaches to air pollution mitigation (EC, 2004).

The CAA, as amended, identifies five major goals for protecting and promoting human health and public welfare. These include:

- Mitigating potentially harmful human and ecosystem exposure to six criteria pollutants, namely CO, NO_2, SO_2, O_3, particulate matter (both PM_{10} and $PM_{2.5}$) and Pb;
- Limiting the sources of and risks from exposure to hazardous air pollutants, which are also called air toxics;
- Protecting and improving visibility impairment in wilderness areas and national parks;
- Reducing the emissions of species that cause acid rain, specifically SO_2 and NO_x; and
- Curbing the use of chemicals that have the potential to deplete the stratospheric ozone layer.

State and local governments are given much of the responsibility to develop, implement, and enforce specific strategies and control measures to achieve the national standards and goals. Although many aspects of the AQM system assume a collaborative relationship between the federal, state, and local agencies, the US-EPA oversees all activities carried out by these agencies. This oversight includes the authority to impose federal sanction and federally devised pollution control plans on non-performing authorities. Under US law the federal courts have a role in air quality management. All air quality related matters promulgated under the CAA are subject to judicial review. The court, usually the Court of Appeals for the District of Columbia, has the power to set aside any regulations, or portions of regulations, deemed to be "arbitrary and capricious" (NRC, 2004). In addition, any private citizen may file a civil action against the US-EPA.

For the purposes of administering the air quality management system, the CAA adopted the air quality control regions (AQCRs) which were previously designated under the 1967 Air Quality

Act. This Act based its measures within ten atmospheric regions grouped according to homogeneous meteorological, climatic and topographical factors. These were divided into 247 air quality control areas (AQCAs) or airsheds, composed of groups of communities to be treated as a unit for the implementation of air quality standards within which non-attainment areas would be designated (McGrory, 1990). The 1990 CAA Amendments updated the boundaries of the original AQCAs based on new statistical data. Each of these AQCAs is required to undertake an inventory of emissions from fixed sources every year and from mobile sources every three years. The emissions inventory from fixed sources is informed either directly from emission testing or continuous emission monitoring (CEM) or the application of emission factors, namely AP 42. The emission factors in AP 42 facilitate the estimation of emissions from a variety of air pollution sources and are considered to be representative of long-term emission averages for all facilities in the source category (US-EPA, 2004).

Based on the NAAQSs and ambient quality monitoring data records, each of the AQCAs is designated as either:

- Non-attainment area - any area that does not meet (or that contributes to ambient air quality in a nearby area that does not meet) the primary or secondary NAAQS for the pollutant;
- Attainment area - any area that meets the primary or secondary NAAQS for the pollutant and does not contribute to the violation of the standards in a nearby area;
- Unclassifiable area - any area that cannot be classified on the basis of available information as meeting or not meeting the primary or secondary NAAQS for the pollutant.

It is important to note that after the promulgation of a new or revised NAAQS each state is required to undertake a review of the designations of the AQCRs under their jurisdiction. Following the initial designation there is further consultation and the US-EPA must make their final area designations within two years of the promulgation of the NAAQS (Walton *et al.*, 2001).

Table 3.2 summarises the number of non-attainment AQCRs declared in the US together with the pollutant that caused the declaration. The table provides two $PM_{2.5}$ values, one based on the standard that was introduced in 1997 and a second value based on an updated standard introduced on 17 December 2006. Non-attainment areas, as defined in the primary legislation, are those areas where ambient air quality fails to achieve the national standards, however, only areas that persistently fail to achieve the national standards are designated (Walton *et al.*, 2001).

Table 3.2: Summary of the AQCRs in the United States as at 18 November 2009 (US-EPA, 2009)

Pollutants	Total Number of Non-Attainment AQCRs
O_3 – 8-hour	52
$PM_{2.5}$ (1997)	39
$PM_{2.5}$ (2006)	31
PM_{10}	47
CO	1
SO_2	9
Pb	2

Figure 3.8 shows the distribution of non-attainment AQCRs in the US. The map does not indicate which pollutant is not in compliance but indicates if the AQCR is a single or multi-pollutant non-attainment area.

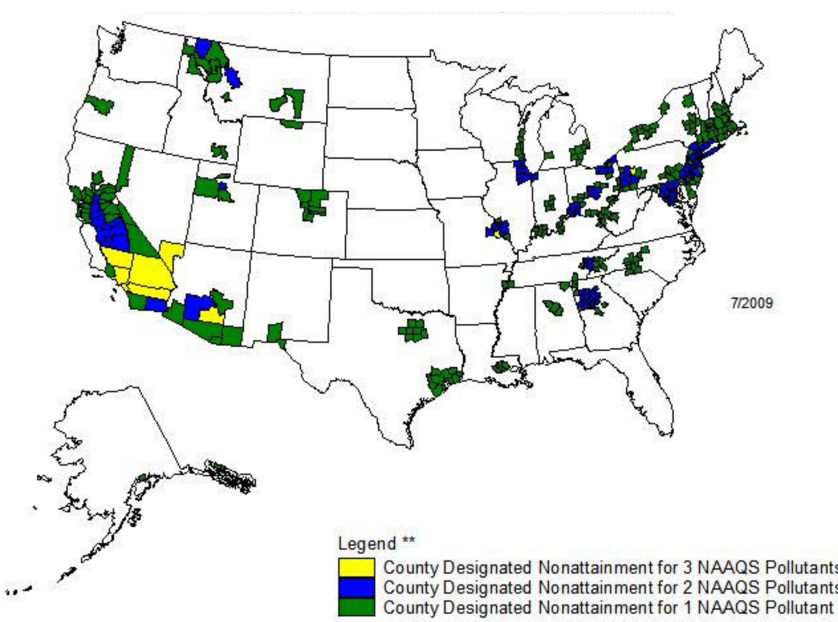

Figure 3.8 Location of non-attainment AQCRs in the US (US-EPA, 2009)

In addition, the CAA classifies non-attainment areas according to the severity of the exceedence of the concentration levels. For example, O_3 non-attainment areas are classified as either marginal, moderate, serious, severe-15, severe-17, or extreme. Similarly, CO and PM_{10} non-attainment areas are classified as moderate or serious. The severity rating influences the scale, nature and timeframes for air quality management interventions. For ozone non-attainment areas the rating of "severe" requires intensive air quality management interventions, namely the use of a photochemical grid model and an enhanced vehicle inspection and maintenance programme, with a 15 – 17 year compliance timeframe, while a "marginal" non-attainment area only requires limited air quality management interventions, namely a regular vehicle inspection and maintenance programme, but only has a three year compliance timeframe (Walton *et al.*, 2001; EC, 2004).

Each AQCR is required to submit a State Implementation Plan (SIP). The SIP and the tribal implementation plan (TIP) is the key tool in the management of the pollutants identified under the NAAQS. The SIP defines the roles and responsibilities of federal, state and local authorities and the associated emission control requirements to either maintain compliance or to bring about compliance with the NAAQS. Accordingly, two separate types of SIPs are developed, either an attainment maintenance SIP if the AQCR is designated as attainment or an attainment-demonstration SIP if the AQCR is designated as non-attainment (EC, 2004). After the US-EPA has approved the SIP, the rules or interventions specified in the plan become federally enforceable.

3.5 Australia

The first step toward a nationally consistent approach to air quality management in Australia occurred in 1990 after an Intergovernmental Agreement on the Environment (IGAE) that lay the foundations for the development of a national framework for air quality management (Commonwealth of Australia, 1992). In 1994, the National Environmental Protection Council (NEPC) was established to set statutory frameworks for the environmental protection of air, water and soil. These frameworks, termed National Environment Protection Measures (NEPMs) specified environmental targets, together with protocols for monitoring and reporting. In 1998, the NEPC introduced the Ambient Air Quality National Environmental Protection Measure (AAQ NEPM) (NEPM, 1998). This established ambient air quality standards for six common pollutants, namely particulates (PM_{10}), SO_2, NO_2, CO, O_3 and Pb, which were applicable in all states and territories of Australia. In 2003, a variation was made to the AAQ NEPM to incorporate advisory reporting standards for $PM_{2.5}$.

The AAQ NEPM included a monitoring protocol to ascertain whether the ambient standards were being achieved in the participating jurisdictions. A participating jurisdiction is defined as either the Commonwealth or a State or Territory of Australia (NEPM, 1998). Due to the vast size of the country, with large uninhabited regions, the AAQ NEPM specified a minimum population threshold of 25 000 as the trigger for the monitoring of pollutants within a region (NEPM, 1998). A region was defined as "an area within the boundary surrounding population centres as determined by the relevant participating jurisdiction" (NEPM, 1998). The Peer Review Committee (PRC) was established to assist the NEPC in its task of assessing and reporting on the implementation and effectiveness of the AAQ NEPM. In 2001, the PRC developed a guidance document (NEPM, 2001) to assist jurisdictions in the selection of regions requiring monitoring and assessment and presented a preliminary identification of the regions by jurisdiction.

The PRC identified three different types of regions that may occur within Australia (NEPM, 2001), namely:

Type 1: A large urban or town complex with a population of 25 000 people or more requiring direct monitoring and contained within a single airshed;

Type 2: A region with no single population centre with 25 000 people or more, but with a total population of 25 000 or more, and with significant point source or area based emissions as to require a level of direct monitoring; and

Type 3: A region with a population of 25 000 people or more but with no significant point or area based emissions, so that ancillary data can be used to infer that direct monitoring is not required.

The initial assessment undertaken by the PRC used the 1996 census data from the Australian Bureau of Statistics. Table 3.3 shows a summary, by state, of the urban centres in Australia with a population > 25 000 inhabitants. While the population data may provide a basis for the preliminary assessment of regions for ambient air quality monitoring it was recommended that this was taken into consideration with other factors such as the airshed characteristics, emission sources in the area, topography and atmospheric dispersion potential (NEPM, 2001). These assessments were left to the discretion of the individual states and territories. The development of the National Pollutant Inventory (NPI) NEPM in 1998 saw the collection and dissemination of information relating to the emission and transfer of 93 different substances. This information formed an integral part of policy and programme formulation for government by assisting in environmental planning and management. This comprehensive information was used in the determination and assessment of urban and regional airsheds.

Table 3.3 Summary of the urban centres in Australia with populations > 25 000 inhabitants (NEPM, 2001)

State / Territory	Number of Urban Centres with a Population > 25 000
New South Wales	15
Victoria	8
Queensland	13
Western Australia	4
South Australia	1
Tasmania	2
Australian Capital Territory	1
Northern Territory	1

The assessment undertaken by the South Australia Environmental Protection Agency (SA EPA) is considered a good example of an individual state assessment (Ciuk, 2002). The SA EPA undertook an assessment of the emissions from aggregate sources within the Adelaide airshed and five regional airsheds. Figure 3.9 shows the location of the study areas. The airsheds selected represented collectively over 79% of the total South Australian population and 85% of the industrial emissions. The assessment also included domestic emissions, transport related emissions and emissions from commercial activities. It is interesting to note that Table 3.3 only shows one urban centre with a population > 25 000, namely Adelaide (978 000), but the SA EPA assessment identified six major airsheds in the state. The combined populations in four of the airsheds exceeded the 25 000 inhabitant threshold, but in two cases, namely Port Lincoln (12 333) and Barossa (14 893), this threshold was not exceeded. This highlights the importance of assessing other factors such as emission sources, topography and atmospheric dispersion potential, when identifying airsheds.

Ciuk (2002) made a number of recommendations to improve the accuracy of the assessment in the future. These included the need to update the emissions inventory within a short period of the next population census to provide a more accurate representation of emissions based on latest demographic information. Further, the emissions inventory for domestic emissions was considered weak and recommendations to improve this in forthcoming assessments were provided. The assumptions relating to emissions from recreational and commercial boating activity may have grossly over or under estimated the true contributions from this sector.

Emissions from bushfires and prescribed burning were excluded from the emissions inventory. This is considered a significant omission, specifically in the regional airsheds. Further improvements in the emissions estimation from motor vehicles and industrial emissions were recommended.

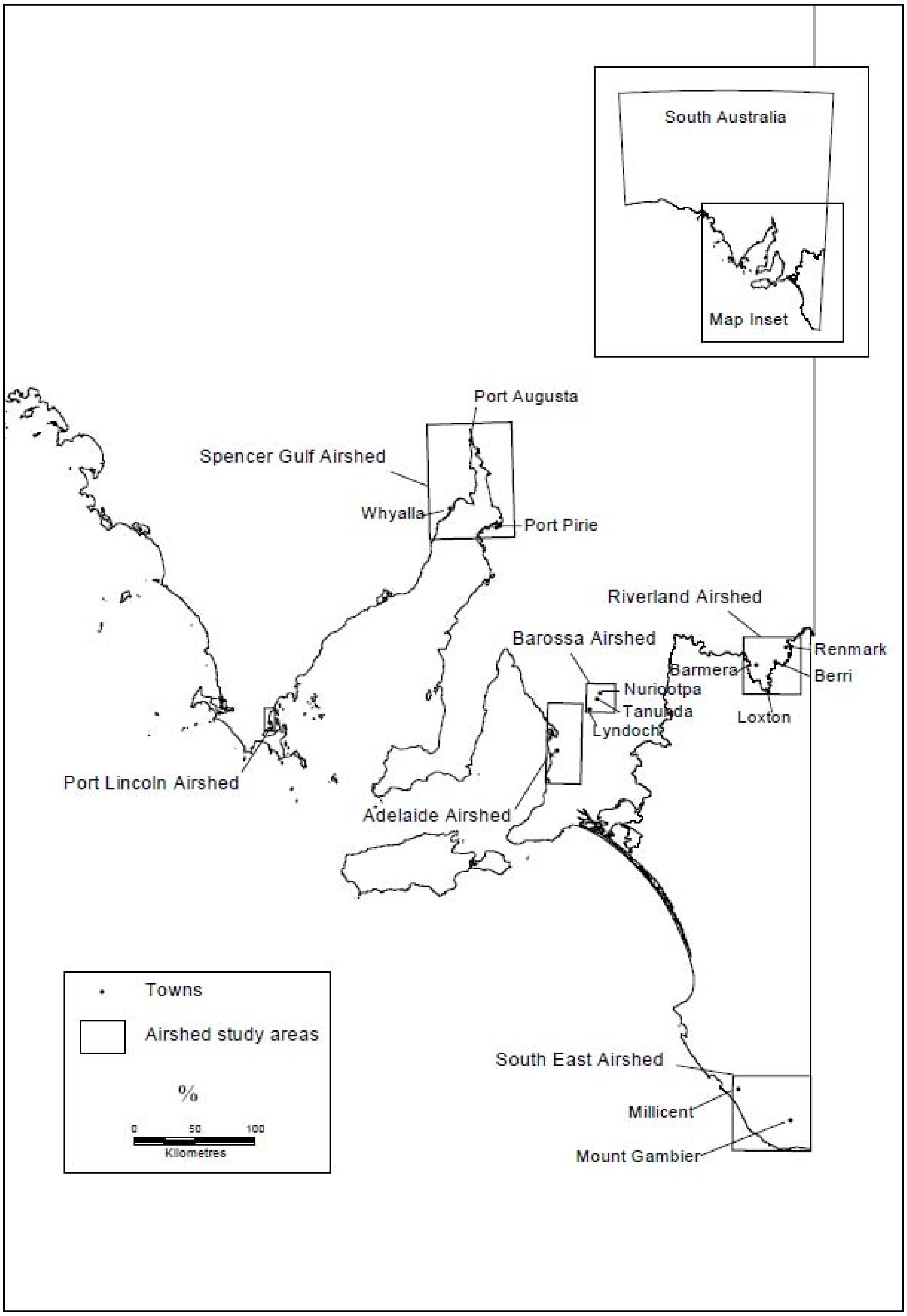

Figure 3.9 Location of the major South Australian airsheds (Ciuk, 2002)

The other states and territories in Australia are at varying stages in the identification of their airsheds, with South Australia, Queensland, New South Wales, Western Australia and Victoria more advanced than the others due to the location of major metropolitan areas, and the associated urban air pollution problems, within these states.

3.6 New Zealand

In New Zealand (NZ) the first air pollution related legislation to be promulgated was the Clean Air Act of 1972. This legislation regulated industrial emissions using the BPM concept (Longhurst *et al.*, 2009). Similarities can be draw with the historical approaches to air pollution control used in the UK and South Africa. The Clean Air Act was nationally administered through the Department of Health and was responsible for the regulation of the larger emission sources. The City and District Councils were responsible for the regulation of smaller emission sources.

The Resource Management Act promulgated in 1991 is the current legislation that controls air quality matters in NZ. The Act promotes sustainable management of NZ's natural and physical resources and is the single piece of legislation under which all environmental matters are managed in NZ (NZ Ministry for the Environment, 2009a). Under the Resource Management Act the 12 regional councils and four unitary authorities are responsible for managing air quality. Regional councils also have a role in ensuring that ambient air quality standards are achieved in their regions. The national government provides guidance and support, through the drafting of national ambient air quality standards, drafting of good practice guideline documents, research, public education and reporting.

Until the introduction of the Resource Management Act, ambient air quality monitoring in NZ had largely been in response to specific, perceived problems, and so was quite limited. The Act shifted responsibility to the regional councils, and monitoring networks were established and expanded throughout NZ during the 1990s. The Act also controls emissions from large industrial sources through air-discharge permits, issued by regional councils. In terms of emissions, domestic fires and motor vehicles contribute most of NZ's air pollutants while industry can also cause localised problems (Sturman and Zawar-Reza, 2002; Bluett, 2006; Cavanagh, 2006; Longley and Olivares, 2008; Longley *et al.*, 2008).

In October 2004, the NZ government introduced 14 national environmental standards for air quality. The 14 standards included seven standards banning activities that resulted in significant emissions of dioxins and furans and other toxics into the atmosphere, five ambient air quality standards, a design standard for new wood burners installed in urban areas and a requirement for all landfills greater than one million tons of refuse to collect greenhouse gases. The ambient standards included CO, NO_2, O_3, particulates (PM_{10}) and SO_2. In June 2009, the NZ Environment Minister announced a review of the environmental standards relating to air quality and appointed an expert panel (NZ Ministry for Environment, 2009b).

The implementation of the standards was linked to the determination of "airsheds" or Local Air Quality Management Areas (LAMAs) for the entire country. The New Zealand Foundation for Research, Science and Technology undertook a research project with the objective of formulating a methodology for determining airsheds or LAMAs, and then completing prototype LAMAs for three District Councils (Fisher *et al.*, 2005). Since the data gathering exercise covered the entire country the draft LAMAs for the entire country were determined. This is one of the few countries to have comprehensively documented the approach taken in the determination of the boundaries of their air quality management areas. The timescale for the project was relatively short, lasting only six months from project initiation to final review. As such, the project relied heavily on readily available information. The process uses four key inputs, each of which is more fully described below. A base year of 2001 was used for the study (Fisher *et al.*, 2005).

3.6.1 Geophysical Boundaries

A key consideration in determining the areas to be included in the NZ LAMA design was local topography, since geophysical features ultimately influence the areas within which emissions travel or reside. The initial work started by defining geophysical boundaries using the orientation of ridgelines, position of valleys and the slopes of hills. The project used a Geographical Information System (GIS) to model and analyse topography at a range of scales.

Since the geophysical boundaries that define airsheds are similar to those that define watersheds, the project used the hydrological analysis tools from the software Arc-GIS 9.0. This tool isolates drainage basins by identifying ridge-lines between neighbouring basins. The key input into this software is a Digital Elevation Model (DEM). A DEM is a digital representation of the land surface and may be defined as a regularly spaced grid of elevation points.

The methodology for isolating ridge-lines in the topography and defining the geophysical boundaries of airsheds is outlined below. The first stage was to smooth the DEM in the x, y and z directions. This has the effect of generalising the height differences across the terrain surface and allows for an easier analysis and definition of ridge-lines. The project started with a 1km resolution DEM as a raster. To smooth the grid, each DEM cell was rounded to the nearest 10m in height (z). This also smoothes the DEM at the coastal margin and has the effect of smoothing the whole DEM vertically. To smooth the DEM spatially (x and y), the "Focal statistics" analysis tool was applied from the Arc-GIS software. This passes a 3 x 3 cell over the DEM and for each group of nine height values and calculates a mean value for that cluster. The resulting output was a smoothed DEM that was suitable for ridge-line analysis. The next phase was the hydrological analysis, involving an assessment of flow directions, flow accumulation and drainage basin location. A cut-off value was applied for merging neighbouring basins. Fisher *et al.* (2005) felt than in order for a geophysical boundary to influence airflow and thus define an airshed, a figure of 200m was appropriate. Therefore, all polygons with a range below 200m were merged. All values above this maintained their own airshed boundary.

The total number of airsheds initially identified, using the above mentioned methodology, was 12 960, with 5 907 (45.5%) in the North Island and 7 053 (54.5%) in the South Island. This large number must be considered within the context of the complexity of the general topography of NZ. Due to the large number of airsheds initially identified, Fisher *et al.* (2005) proposed a technique for trimming this number. The airsheds were subjected to analysis based on the range in heights per drainage basin, as well as the mean height of the basin itself. This analysis reduced the total number of airsheds to 4 911. The project team acknowledged that further reduction or trimming of the total number of airsheds was required.

3.6.2 Emissions Information

One of the major determinants of the LAMA identification process was particulate matter, specifically PM_{10} emission density. Emissions from a variety of sources were combined to produce an emissions density per census area unit (CAU). The purpose of this criterion was to identify high-density emission areas across NZ. The emission sources considered domestic fuel burning, motor vehicles and industries. The methodology for the emission determination for each of these sources is described in more detail below.

Domestic PM_{10} emissions were based on the 2001 census data which included information identifying the number of dwellings in each CAU that used wood, coal, gas, electricity and other heating methods. This information was used in conjunction with estimates of average daily fuel use for both wood and coal, and estimates of average emission rates for each fuel to estimate PM_{10} emissions for each CAU. Fisher *et al.* (2005) acknowledged that the methodology was subject to a number of major limitations. The main concern was that the approach did not allow for variations in types of burners. This could be significant, as areas with a large number of modern low emission burners would be assumed to have the same emission rate as areas dominated by older burners or open fires. Similarly, the estimates of fuel use were not location or appliance specific. It was recommended that future work be undertaken, based on more accurate home heating surveys, to refine the accuracy of the emissions from this source.

Estimation of PM_{10} emissions from on-road vehicles involved the collection and use of data from three principle data sources, i.e. the total number of vehicle kilometres travelled (VKT), the number and type of vehicles that comprise the national fleet and the emission rate of PM_{10} by each particular vehicle type. The vehicle kilometres travelled was obtained from the Ministry of Transport (MoT) and was based on a 1994 National Traffic Database. The database lists virtually every section of public road in NZ together with information regarding the length of the section of road, an estimate of the average annual daily traffic, the road classification (urban arterial, rural etc.), speed limit and responsible authority. Information was available throughout NZ with counts made in every Territorial Local Authority (TLA). The MoT disaggregated the national VKT data into 14 regions and further processing was done to ensure detailed information was available in every TLA. The motor vehicle fleet data were obtained from the Land Transport Safety Authority Vehicle Registration database. The 2004 data were used in the study as 2001 data were not readily available. The national database was disaggregated into TLA and into eight vehicle classes. The TLA fleet data were used to determine the VKT travelled and the PM_{10} emissions rates from motor vehicles. A local database was used to calculate PM_{10} tailpipe emission factors for the eight vehicle classes considered.

Fisher *et al.* (2005) highlighted that the project only considered on-road use of motor vehicles. The project excluded emissions from off-road use and other forms of transportation, i.e. rail, ships and aircraft. It was recommended that other sources of transport emissions should be included in future revisions of the inventory.

The industrial PM_{10} emission from all major dischargers was estimated. The initial focus was on combustion related emissions, but this was extended to include relevant process emissions, including some quarries and mining activities. Emission factors were applied to the activity data to estimate the quantity of emissions from each source. Emission factors used were from the US-EPA AP42 database (US-EPA, 2004). To account for the varying quality of emission calculations, a reliability index was introduced (Fisher *et al.*, 2005). The reliability index ranged from 1, which signifies well justified emissions data obtained through continuous emission monitoring, to 5, which is essentially an educated guess. When the exact location of an operation was not clear, an effort was made to find the location through various web-based sources. Once a street address or locality was identified, the co-ordinates were found using mapping software. When the exact location was unknown but the general area was identified a subjective estimate was made. The use of this reliability index may create an overly conservative emission estimate, since the US-EPA AP42 database already includes a confidence measure. The methodology did not indicate the weighting the reliability index carried, and as such it is not possible to assess the impact this may have on the results.

3.6.3 Meteorological Effects

The LAMA boundaries defined in the study are defined primarily by emission patterns and geographical barriers but the meteorological effects determine if estimated concentrations within a CAU will extend beyond that CAU. Thus the effects of neighbouring CAUs with high emissions, impacting on each other, need to be considered if they can be merged together into a single LAMA. The aim is to use a model of dispersion from different sources to estimate levels of PM_{10} arising from emissions under worst case meteorological conditions. A simple, analytical model for urban air pollution relating concentration, emission rate and meteorology was applied as shown in Equation 3.1 (Fisher *et al.*, 2005).

$$X = cQ / U \qquad 3.1$$

Concentration is denoted by X, area source strength by Q, wind speed by U and parameter c is a simple indicator of the amount of dispersion that the emissions experience in the atmosphere. Parameter c is determined by Equation 3.2

$$c = (2/\pi)^{1/2}\, x^{1-b}(a(1-b))^{-1} \qquad 3.2$$

Parameter c is further described by parameters a and b relating to turbulence and stability in the atmosphere at the location and time of interest. Parameters a and b are stability dependant, and related to the vertical diffusion coefficient σ_z by Equation 3.3.

$$\sigma_z = ax^b \qquad 3.3$$

where x is the distance downwind. This model is recommended by the European Environment Agency (EEA) for preliminary assessment of area sources under the EC air quality directives. Inputs into the model are interpreted as the daily domestic PM_{10} emission rates for each CAU, and the CAU area (as Q is the emission rate per unit area). Other assumptions include that emissions are uniformly distributed within each CAU; a=0.06, b=0.71 for stable conditions under low wind speeds; the values of a and b are 10-minute averages, so a (and thus σ_z) is scaled by $(60/10)^{0.2}$ to give hourly average concentrations; the worst case wind speed is 1.5 m/s and all emissions occur during the night when the worst case wind speed occurs.

3.6.4 Final Outputs

The geophysical boundary data were combined with the other GIS referenced criteria data, i.e. administrative boundaries, emissions, meteorology, to refine the airshed boundary determination. The project team reduced the final number to 161 areas. Figure 3.9 shows the preliminary outputs from the project. The LAMAs are divided into three categories, depending on the air pollution impact potential of the area. 60 of the LAMAs are coded as Category 1, which indicates that enhanced air quality management intervention will be required, 85 of the LAMAs are coded as Category 2, which indicates further review and assessment is required in these areas, while the balance of the country is coded as Category 3, indicating that no air quality problems are anticipated. This preliminary review has been refined and as at September 2005 there were 42 LAMAs where air quality could exceed the national ambient standards (Bluett, 2006). All but one of the 42 LAMAs have been gazetted due to known or potential concerns about particulate matter (PM_{10}) and the remaining LAMA has the potential to breach the sulphur dioxide and particulate matter (PM_{10}) standards.

3.7 Summary of International Approaches

All of the international approaches reviewed are extremely data intensive. The EU approach to zone identification relies on over 4 000 ambient monitoring stations to allow comparison with the ambient air quality standards specified in the Daughter Directives. The EU approach recommends the use of administrative boundaries for zone delineation. The UK approach to AQMA boundary determination is a combination of ambient air quality monitoring and dispersion modelling. The dispersion modelling component is reliant on comprehensive emissions inventories. Again, the use of administrative boundaries is also recommended. The US approach to the identification of non-attainment areas relies on ambient air quality monitoring stations to allow comparison with NAAQS. Here again, the use of administrative boundaries is recommended when delineating a non-attainment area. The NZ approach is considered to be the most comprehensive method assessed. The method combines topography, meteorology and emissions, with administrative boundaries providing guidance. The methodology is also considered data intensive as this method required DEM data, detailed emission inventories for all industrial sites, detailed vehicle count and profile data, detailed domestic emission data and detailed meteorological data.

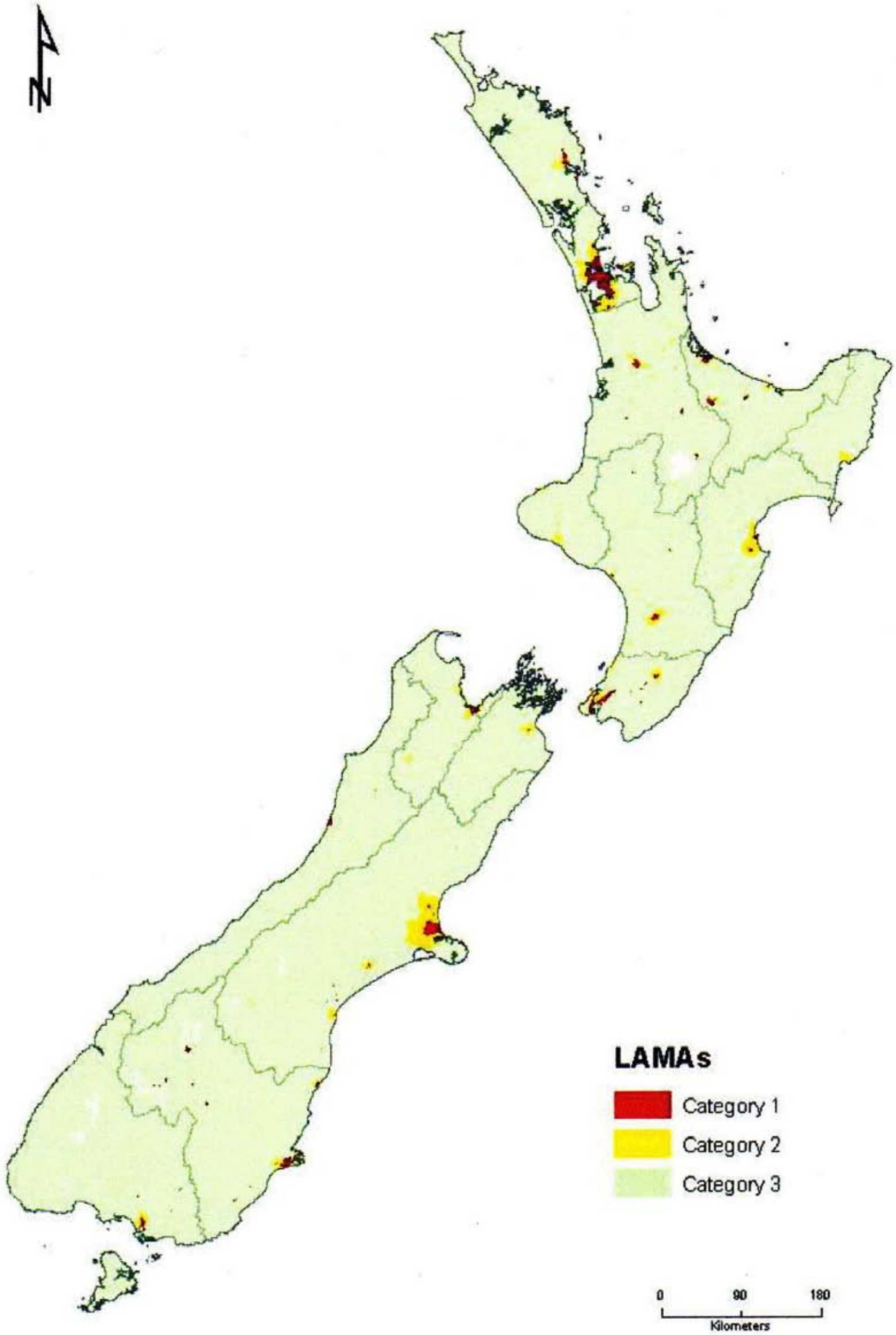

Figure 3.10 Preliminary local air management areas for New Zealand (Fisher *et al.*, 2005)

It must be noted that all the countries and regions assessed in this chapter all rely on the same effects-based air quality management philosophy. This is the same approach to air quality management that South Africa is pursuing under the AQA. Table 3.4 provides a summary of each of the international approaches to defining the boundaries of air quality management areas or regions.

Table 3.4 Summary of international approaches to defining air quality management areas

Country / Region	Approach to Defining Air Quality Management Areas
European Union	Ambient air quality monitoring and administrative boundaries
United Kingdom	Ambient air quality monitoring, dispersion modeling and administrative boundaries
United States	Ambient air quality monitoring and administrative boundaries
Australia	Population density, emission inventories, topography and atmospheric dispersion potential
New Zealand	Topography, emission inventories and atmospheric dispersion potential

The approach of using ambient air quality monitoring results to assist in the definition of the boundaries of air quality management areas is not readily applicable in South Africa, due to the paucity of the ambient air quality monitoring stations in the country. Projects are being implemented to expand the national ambient monitoring network, so in time this approach may be applicable in South Africa. The use of administrative boundaries is something that is readily applicable in South Africa. The AQA provides guidance on the roles and responsibilities of all spheres of government so the use of administrative boundaries in the South African context is considered appropriate. The approach of using emission inventories and dispersion modeling is not readily applicable to all areas of South Africa, due to the lack of a national emissions inventory. Emissions inventories do exist for some of the major metropolitan areas and some regions, however, these inventories are not readily available, cover different time periods and are not consistent in terms of the pollutants reported. Phase II of the SAAQIS project will see the development of the national emissions inventory, so in time this approach may be applicable in South Africa. The use of population density, topography and atmospheric dispersion potential is directly applicable in the South African context. This information is readily available for the entire country.

CHAPTER 4
METHODOLOGY FOR THE DELINEATION OF BOUNDARIES OF AIR QUALITY MANAGEMENT AREAS IN SOUTH AFRICA

4.1 Introduction

This chapter will outline the proposed methodology for the delineation of boundaries of air quality management zones in South Africa. The methodology chosen was based on a combination of assessment criteria that are currently used internationally and other criteria specific to the South African context. The methodology proposed for South Africa has been determined based on the lack of readily available air quality information, whilst ensuring the scientific defensibility of the resultant outputs. The methodology proposed could also be applied internationally, specifically in countries where ambient air quality and emissions data are not readily available

Based on the international review detailed in Chapter 3 and an understanding of the limitation of ambient air pollution and emissions data readily available in South Africa, the following criteria have been selected as the criteria to be used in the delineation of the boundaries of air quality management zones in South Africa.

The first criterion, and a common thread in most international methodologies, is the use of agreed administrative boundaries as indicating the extent of the air quality management zones. Population density is the second criterion that will be used in the assessment. Whilst some international methodologies caution against the use of this criterion due to its dynamic nature (EC, 2003), an argument for its use in the South African context will be presented below. The third criterion will be the use of emissions density. The emissions parameter will be determined from a variety of emission sources, i.e. industrial, mining and domestic emissions. In the absence of actual emissions data for all sources, proxy methodologies are presented below based on readily available information. The final criterion will be the use of topographical features to determine the boundaries of air quality management zones. Each criterion will be mapped on a GIS and based on the analysis of the outputs the preliminary boundaries of the air quality management zones in South Africa will be delineated.

4.2 Boundary Criteria

4.2.1 Geopolitical Boundaries

The use of geopolitical boundaries in defining the boundaries of air quality management zones is a common practice internationally (Van Aalst *et.al.*, 1998; EC, 2003; Woodfield *et al.*, 2002; Fisher *et al.*, 2005). The strength of using this criterion is that all geopolitical boundaries are agreed boundaries with a specific spatial representation. In some cases the boundaries are selected based on physical / topographic criteria i.e. rivers and ridges. This falls in line with the other criteria that have been selected as the basis for determining the boundaries of air quality management zones. In other cases the boundaries have been selected based on other parameters and this will create situations where the combination of adjacent areas may be required.

In South Africa the determination of geopolitical boundaries is controlled by the Municipal Demarcation Board. In terms of Section 155 of the Constitution, the Municipal Demarcation Board is an independent authority responsible for the determination of municipal boundaries. The Board's status as an independent authority is also protected by Section 3 of the Local Government: Municipal Demarcation Act, 1998, and various judgements by the Constitutional Court. In addition to the determinations and re-determination of municipal boundaries, the Board is also mandated by legislation to declare district management areas; to delimit wards for local elections; and to assess the capacity of municipalities to perform their functions.

Geopolitical boundary demarcations are subject to change and for the purpose of this dissertation the boundaries as at 1 June 2009 are the geopolitical boundaries used in this study. South Africa is currently divided into nine separate provinces (Fig. 4.1). Table 4.1 shows the breakdown of the country according to province, metropolitan, district and local municipalities. It is important to note that under the AQA the district and metropolitan municipalities will become the atmospheric emission licencing authorities. As such, the district and metropolitan municipality boundaries will be the primary factor when considering the boundaries of air quality management areas, however the local municipality boundaries may be used to refine the final boundary. The results presented in Chapter 5 will be presented at both the district and local municipality level, with the metropolitan municipality results presented on both levels.

Table 4.1: Municipal demarcation of South Africa as at 1 June 2009 (Municipal Demarcation Board, 2009)

Province	Metropolitan Municipalities	District Municipalities	Local Municipalities
Eastern Cape	1	6	38
Free State	0	5	20
Gauteng	3	3	9
KwaZulu-Natal	1	10	50
Limpopo	0	5	25
Mpumalanga	0	3	18
Northern Cape	0	5	27
North-West	0	4	20
Western Cape	1	5	24
Total	6	46	231

The Municipal Demarcation Board also divides the local municipalities further into wards for the purposes of local elections. Whilst information exists at the ward level, it was decided for the purposes of this dissertation to use the local municipal level as the lowest level of geopolitical boundary. All of the other information sources used in this dissertation will be assessed at the local municipality level. For readers not familiar with South African geography, it is recommended that they use the Municipal Demarcation Board website (www.demarcation.org.za) for reference purposes. The website provides maps at the national, provincial, district and local municipality level. The maps may provide to assistance in the interpretation of the results presented in Chapter 5 and 6 as it was impractical to generate annotated maps at the scale presented.

4.2.2 Population Density

Population density is the second criterion to be used in the determination of the boundary of air quality management zones in South Africa. The EU (Vixseboxse and De Leeuw, 2007) provides guidance that the use of population density in the designation or determination of air quality management areas is not advisable. The argument put forward by the EU is that population densities fluctuate, and as such, is not a criterion they recommend. In the South African context the use of the population density criterion to determine the boundary of the air quality management zone is considered appropriate due to the fact that a large proportion of South Africa's urban and peri-urban population are a significant source of air pollution relating to domestic fuel burning. In addition, urban South Africans are highly dependent on road transportation as the primary means of commuting, due to the poorly developed public transport system. As such, high population density may also be a good proxy indicator of air pollution.

This matter is complicated in the South African situation by the fact that a high population density may also occur within rural areas. This is mainly due to the apartheid legacy which saw the development of rural bantustans. As such, careful differentiation between rural and urban areas is required when using this criterion.

The 2001 National Census data are the population information used in this study. A mid-year population estimate was undertaken in 2008, however this update was a high level assessment and did not provide population estimates at the local government level. It must be noted that the municipal demarcation used in the 2001 census differs slightly from the current demarcation. The census data, specifically the geophysical references, will be adjusted to align with the current demarcation. The population density has been calculated in all of the municipal areas in the country, down to local municipality level. The detailed information is included in Appendix 2. Table 4.2 provides the population density in each of the six metropolitan municipality areas.

Table 4.2: Population densities in the metropolitan municipalities (after StatSA, 2004)

Name of Metropolitan Municipality	Population (2001)	Area (km^2)	Population Density (people/km^2)
City of Cape Town	2 893 246	2 987.4	968.5
Nelson Mandela Bay (Port Elizabeth)	1 005 778	1 958.9	513.4
Ethekwini (Durban)	3 090 121	2 291.9	1 348.3
City of Johannesburg	3 225 812	1 645.0	1 961.0
City of Tshwane (Pretoria)	1 985 983	2 174.6	913.3
Ekurhuleni (Kempton Park)	2 480 277	1 924.4	1 288.8

The most densely populated province is the Gauteng Province, with an average population density of 519.6 people/km^2, while the least densely populated province is the Northern Cape Province with an average population density of 2.7 people/km^2. The national average population density in South Africa is 36.7 people/km^2 (United Nations, 2009). The global average population density is 45.2 people/ km^2 (United Nations, 2009). Population densities range from 18 131 people/km^2 in Macau (People's Republic of China) to 0.026 people/km^2 in Greenland (Denmark) (United Nations, 2009). Several of the most densely-populated territories in the world are city-states, microstates, micronations, or dependencies. These territories share a relatively small area and a high urbanisation level, with an economically specialised city population drawing also on resources outside the area. In the case of South Africa this can be likened to the urban conurbation of Johannesburg, with a high level of urbanisation supported by resources produced outside of the Gauteng province. High population density is characterised as more than 1000 people/km^2 (Elsom, 1999).

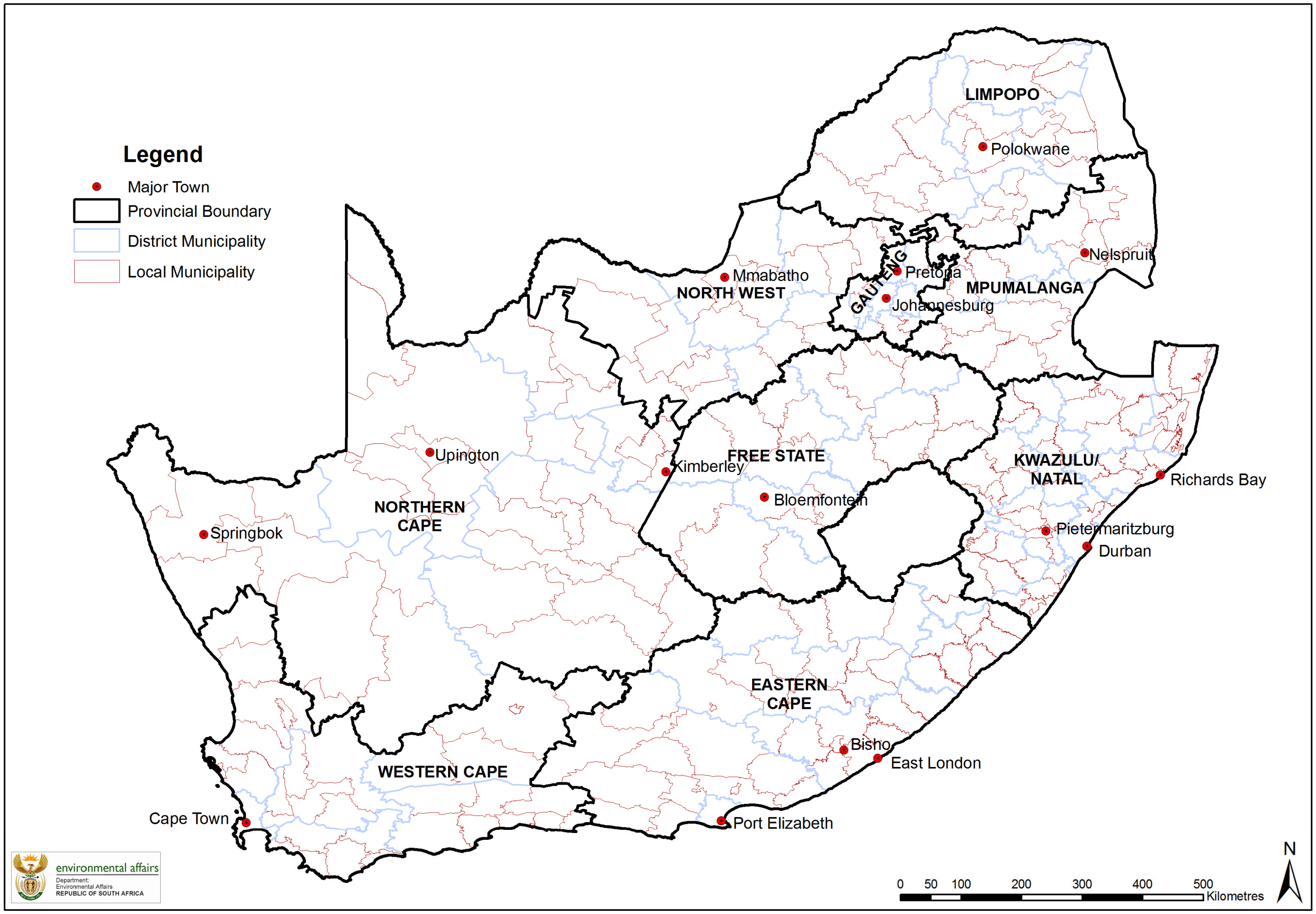

Figure 4.1 Geopolitical boundaries of South Africa as at 1 June 2009

4.2.3 Emissions

4.2.3.1 Industrial Sources

The industrial emissions assessed as part of this dissertation are derived from the APPA Registration Certificates database. This database is the only national registry of large industrial operations. An electronic database was generated as an output of the APPA Registration Certificate Review project, which sought to centralise the APPA Registration Certificates which were issued and maintained in regional offices. All the registration certificates from the Durban, Cape Town, Boksburg and Pretoria regional offices were consolidated in the Pretoria offices of the DEA in 2007. The contents of all the registration certificates were captured into a common electronic database and a uniform hard-copy archive was developed. The final output was an electronic database of 2578 companies that were registered to operate scheduled processes across the country. The number of companies that are coded as operational in the database is 1509. The actual number of operational companies is expected to be lower due to the fact that several companies no longer operate scheduled processes on their premises but have not officially withdrawn or cancelled their registration certificates. This excludes companies that are operating scheduled processes without the required registration certificates.

Figure 4.2 shows the provincial breakdown of industries registered in the APPA Registration Certificate database. The numbers adjacent to the province name indicates the actual number of registration certificates in each province and a percentage of the national total. Gauteng province has the highest number of registration certificates, accounting for over 30% of the total registration certificates, while the Northern Cape province has the lowest number of registration certificates, accounting for just over 2% of the national total.

The electronic database had a number of shortcomings that needed to be addressed before the information could be considered useful for this dissertation. During the data capturing phase of the project, quality control was undertaken on a sample basis. This allowed some errors to go undetected during the data capture phase. The most common error was where a company was not correctly captured in terms of its geographical location. Initial work involved a comprehensive review of the database to ensure the accuracy of the geographical coding of each company.

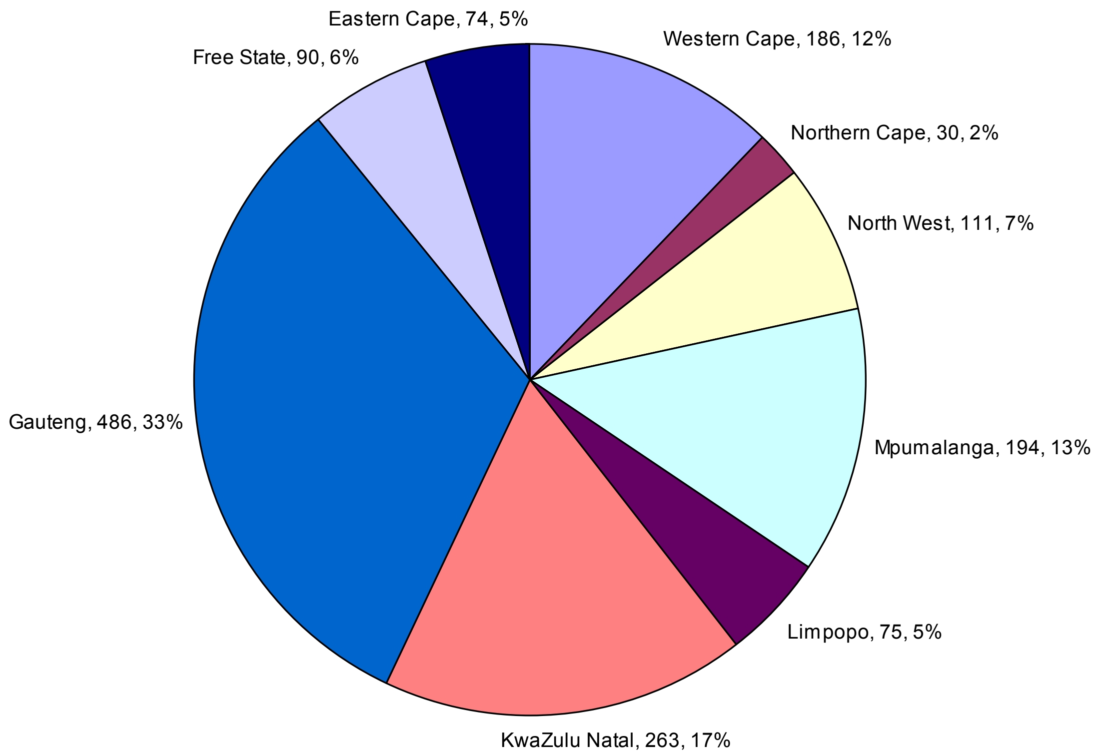

Figure 4.2: Provincial summary of the distribution of registration certificates in South Africa (DEAT, 2009b)

Due to the lack of a comprehensive national emissions inventory and the absence of regular emissions reporting as a condition in registration certificates, it was necessary to base the industrial emissions impact from each site on a proxy methodology. A common method of overcoming the lack of site specific emission information is the use of emission factors, such as the US-EPA AP42. The use of emission factors requires knowledge of the specific industrial process taking place on the site, an understanding of the production capacity or throughput of the process and an understanding of the pollution abatement equipment installed. The registration certificates issued for each of the scheduled processes operational in the country do not contain such detailed information. This information is also not readily available for illegal / unregistered operations. As such an alternative proxy methodology was required to assess the industrial emission impact.

During the APPA Registration Certificate Review project a prioritisation matrix was designed primarily based on the identification of sources contributing significantly to local air pollution resulting in human health and welfare impact potentials. The primary objective of the prioritisation matrix was to allow for the identification of the top 50 polluters in the country (DEAT, 2006c). The APPA Registration Certificate Review project found it difficult to identify specific individual companies and reverted to a sector-based approach, where six industrial sectors were identified. These sectors included Primary Iron and Steel, Petrochemical Refining, Ferroalloy Production (Ferro-Vanadium, Ferro-Chrome and Ferro-Manganese), Primary Aluminium, Pulp and Paper and Coal-fired Power Generation (DEAT, 2006c). In total, 63 individual operations were identified from the process, accounting for ~ 80% of the industrial emissions in the country, but accounting for only 4.1% of the total number of registration certificates. A modified methodology was followed during this research to take account of the assessment at the local government level and the improved geographical information available following the comprehensive review of the database. As part of this research it was decided to remove the public profile criterion from the assessment. The public profile criterion provided an indication of the number of air pollution related complaints received regarding a specific company and also the level of negative press coverage received. It was removed as it was considered a duplication of the parameter assessed under air pollution control officer (APCO) findings.

The industrial emissions impact assessment was divided into three separate categories, namely source impact, receptor impact and compliance status. The source impact of an industrial site was assessed by quantifying the number of individual registration certificates held by the company. This assessment was expanded by also assessing the air pollution impact potential and hazard rating of each industrial emitter. The hazard rating was subjectively determined based on the following criteria:

- Possible quantity and impact potential of common criteria pollutants (SO_2, PM_{10}, NO_x and CO);
- Potential for generating toxins such as benzene, dioxins and furans, carcinogenic metals such as cadmium, manganese, hexavalent chromium, arsenic, polyaromatic hydrocarbons, polychlorinated biphenyls, acrylonitrile, 1.3 butadiene, acedaldehyde, asbestos, quartz, etc.;
- Potential for upset emissions;
- Potential for accidents likely to result in significant atmospheric emissions;
- Height of discharge of emission; and
- Odour impact potential.

In order to ensure consistency with the APPA Registration Certificate Review project the same hazard rating was applied as calculated in the original project. A summary of the hazard rating scores for each of the industry sectors is shown in Figure 4.3.

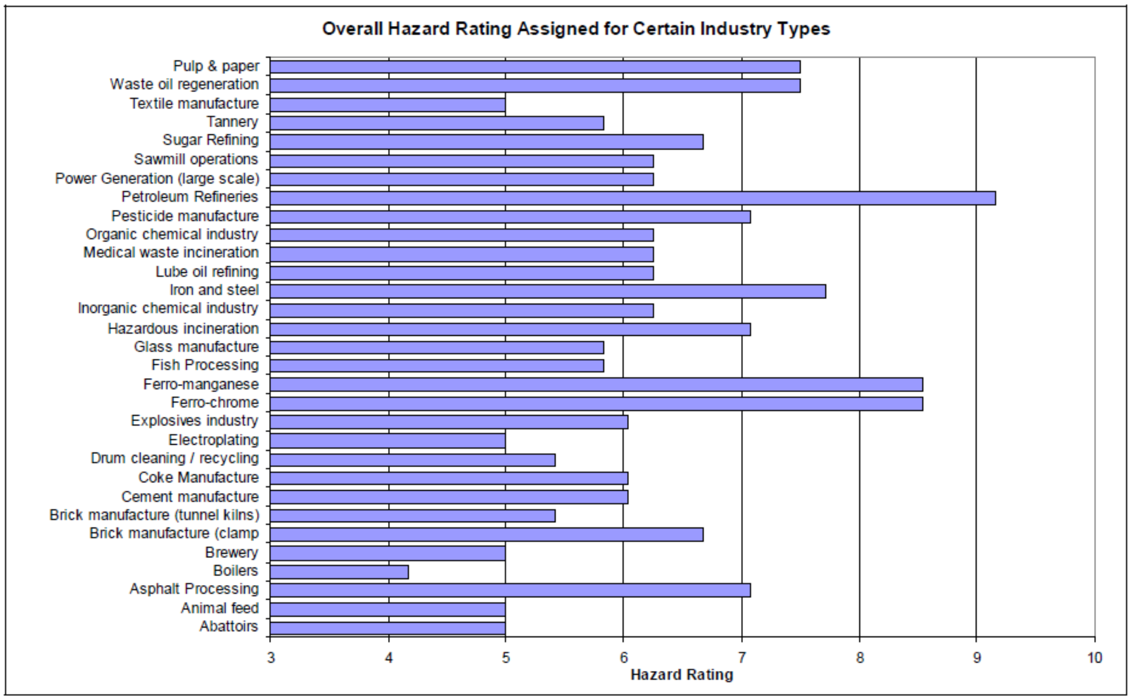

Figure 4.3: Overall hazard rating assigned to certain industry types (DEAT, 2006c)

The majority of the industries assessed had hazard ratings of between 4.2 and 5.8 out of a possible 10. Petroleum refineries were assessed to have the highest hazard rating (9.2), followed by ferro-chrome and ferro-manganese (8.5), iron and steel (7.7), waste oil regeneration (7.5) and pulp and paper (7.5). Small-scale boiler operations were assessed to have the lowest hazard rating (4.2). It must be noted that this hazard rating was only calculated for scheduled processes, operated in terms of the APPA, and excludes smaller industrial operations that fall below the threshold requiring registration. In the case of industrial boilers, all boilers capable of burning more than ten tons of coal per hour require registration. All other smaller boilers must be registered with the local authority as a fuel burning appliance.

The receptor impact of the rating was assessed by determining the exposure potential of the population in the vicinity of industrial operations. The receptor category was modified from the original methodology to assess the exposure of the population within the entire local municipality, instead of a 3km radius from the plant. The APPA Registration Certificate Review project reported that the geographical location of each operation was only known for 35% of the total database (DEAT, 2006c). The uncertainty in the location of the industrial operations may be attributed to the following reasons. The limited human resources prevented regular compliance inspections at all facilities, as such officials undertook inspections on a reactive basis, usually after receipt of a complaint. Changes to the municipal demarcation system in the late 1990s resulted in significant changes to location descriptions. Old location descriptions reflected in registration certificates were in some cases difficult to convert to the new municipal demarcations. This problem was compounded by the lack of up to date telephone numbers, contact personnel and postal addresses. This was partially resolved during the review of the APPA Registration Certificate database undertaken for this research, but significant uncertainty still exists for ~ 50% of the database. Due to the uncertainty in the actual location of some of the smaller operations this approach is considered more conservative. This is also considered an improvement in the methodology due to the errors in the database relating to geographical location of operations. The receptor impact also assesses the potential for cumulative impacts from other industrial emission sources.

The compliance status of the rating assessed compliance performance of the individual companies. The potential for compliance monitoring was assessed by determining the last time any of the registration certificates on the site were reviewed. The CAPCO issues two types of registration certificates, either a provisional certificate or a final certificate. In the case of a provisional certificate the operator must demonstrate compliance with the conditions of the registration certificate before a final certificate can be issued. A provisional registration certificate has a specified validity period, ranging from three months to five years. A final registration certificate has no specified validity period, as such, when a final registration certificate is issued this permits the plant to operate indefinitely. In some cases the database revealed that plants were operating under registration certificates issued in the 1970s. The compliance category also reviews the frequency of complaints received regarding a particular operation and other non-compliance issues noted by the APCOs assigned to each plant.

Table 4.3 shows the criteria assessed within each of the assessment categories and the scoring assigned. The scoring parameters for each of the criteria are largely consistent with the methodology used in the APPA Registration Certificate Review project, with minor amendments in the receptor category. The source impact category scored the industrial impact in two sub-categories, namely scale of operation and air pollution potential.

Table 4.3: Scoring parameters for each criterion (after DEAT, 2006c)

Source Impact Category				Receptor Impact Category				Compliance Status Category			
Scale of Operation		Air Pollution Potential		Exposure Potential		Cumulative Impacts Potential		Compliance Monitoring Potential		Operator Compliance	
No. of RC's Held	**Score**	**Industry Hazard Rating**	**Score**	**Local Municipality Population**	**Score**	**Location**	**Score**	**Date of Last Amendment to RC**	**Score**	**APCO Findings / Complaints / Directives Issued**	**Score**
1	20	HR5	20	< 50 000	20	Rural	25	2005 – current	0	1	0
2 - 5	40	HR4	40	50 001 – 150 000	40	Predominately Rural with Urban Pockets	50	2000 – 2004	25	2	25
6 - 10	60	HR3	60	100 001 – 300 000	60	Predominately Urban with Rural Pockets	75	1990's	50	3	50
11 - 15	80	HR2	80	300 001 – 500 000	80	Metro / Priority Area	100	1980's	75	4	75
> 15	100	HR1	100	> 500 001	100			Before 1980's	100	5	100
Blank	0	Blank	0	Blank	0	Blank	0	Blank	0	Blank	0

In terms of the scale of operation, the higher the number of registration certificates held by an industrial operation at a single site, the higher the rating score. Of the 1509 operational companies registered in terms of the APPA, 1338 (88.7%) have a single registration certificate. The balance of the companies hold multiple certificates, with Sasol Secunda (77) holding the most registration certificates on a single site. In terms of the hazard rating, the results presented in Figure 4.3 were divided into hazard rating bands, with the higher hazard rating attracting a higher rating score. The banding for the hazard rating was as follows, HR1 indicated a hazard rating of greater than 8.1, HR2 indicated a hazard rating of 7.1 – 8.0, HR 3 indicated a hazard rating of 6.1 – 7.0, HR 4 indicated a hazard rating of 5.1 – 6.0, while HR5 indicated a hazard rating of less than 5.0. By example, a petrochemical refinery with a hazard rating of 9.2 would be classified in the HR1 band, while a small boiler with a hazard rating of 4.2 would be classified in the HR 5 band.

The receptor impact category scored the industrial impact in two sub-categories, namely exposure potential and cumulative impact potential. In terms of the exposure potential, the total population of the local municipality in which the industry was located was assessed. Industries located in local municipalities with high population were assessed to pose a greater exposure potential. In terms of the cumulative impact potential the overall location of the industry was assessed in relation to other pollution sources, with isolated rural operations assessed to have a lower impact potential as opposed to industries located within known air pollution hotspots.

The compliance status category scored the industrial impact in two sub-categories, namely compliance monitoring potential and operator compliance. As highlighted previously, the historical compliance and enforcement of the APPA legislation was limited due to capacity constraints. In terms of the compliance monitoring potential, the industries were assessed based on the date the registration certificates were issued. Industries with registration certificates issued within the last five years were deemed to contain operational conditions in line with the NEMA principles relating to environmental management, while older registration certificates were deemed to be out of line with modern environmental principles. By example, a registration certificate issued in the 1970s contained no emission limits but was considered legally valid, whereas a registration certificate, in the same industrial sector, issued in 2009 would contain emission limits in line with best available technology (BAT). In terms of the operator compliance, the industries were assessed based on the number of public complaints received, negative APCO audit report findings and compliance directives issued within the last ten years. The higher the number of complaints, negative audit findings or compliance directives issued, the greater the assessed score. Information to inform this assessment was gathered during the APPA Registration Certificate Review project and was augmented by feedback received during Working Group II Meetings (National – Provincial Air Quality Officers Forum) which are held on a quarterly basis.

Figure 4.5 shows the weightings applied to the criteria, sub-categories and categories to derive an impact score for each individual plant. The weightings are slightly modified from the original weightings applied during the APPA Registration Certificate Review project to accommodate the changes made to the assessment criteria for this research. Each individual criteria score, as determined using the scoring parameters detailed in Table 4.3, is weighted at 100% of the assessed score. For example a company holding five registration certificates would receive a score of 40 and this score would be considered in the weighting exercise. Once all scores for each of the criteria have been determined, the weighting exercise proceeds to the sub-category level. At this level the first of the differential weighting occurs. The percentage weighting specified is applied against the criteria score. Following the application of the initial weighting at the sub-category level, the scores obtained within each of the three assessment categories are summed. The resultant scores represent the individual category scores which are further weighted to generate a final assessment score. Box 4.1 below shows a worked example of the weighting system.

Box 4.1: Worked Example of Industrial Weighting System

Company X is a petrochemical refinery located in Johannesburg. It currently holds 15 registration certificates and the last amendment to any registration certificate took place in 2002. Within the last 10 years there have been two public complaints regarding odour and a compliance directive was issued for the company to address fugitive emissions from their tank farm.

Source Impact Score

No. of RC's Held = 15 – Score 80 (Weighting 30%) = 24

Industry Hazard Rating = 9.2 = HR1 – Score 100 (Weighting (70%) = 70

Final Source Impact Score = 94

Receptor Impact Score

Local Municipality Population = 3 225 812 – Score 100 (Weighting 70%) = 70

Location = Metro / Priority Area – Score 100 (Weighting 30%) = 30

Final Receptor Impact Score = 100

Compliance Status Score

Date of Last RC Amendment – 2002 – Score 25 (Weighting 50%) = 12.5

APCO Findings / Complaints / Directives – 3 – Score 50 (Weighting 50%) = 25

Final Compliance Status Score = 37.5

Final Impact Score

Final Source Impact Score (94) (Weighting 40%) = 37.6

Final Receptor Impact Score (100) (Weighting 25%) = 25.0

Final Compliance Status Score (37.5) (Weighting 35%) = 13,1

Final Industrial Assessment Rating for Company X = 75.7

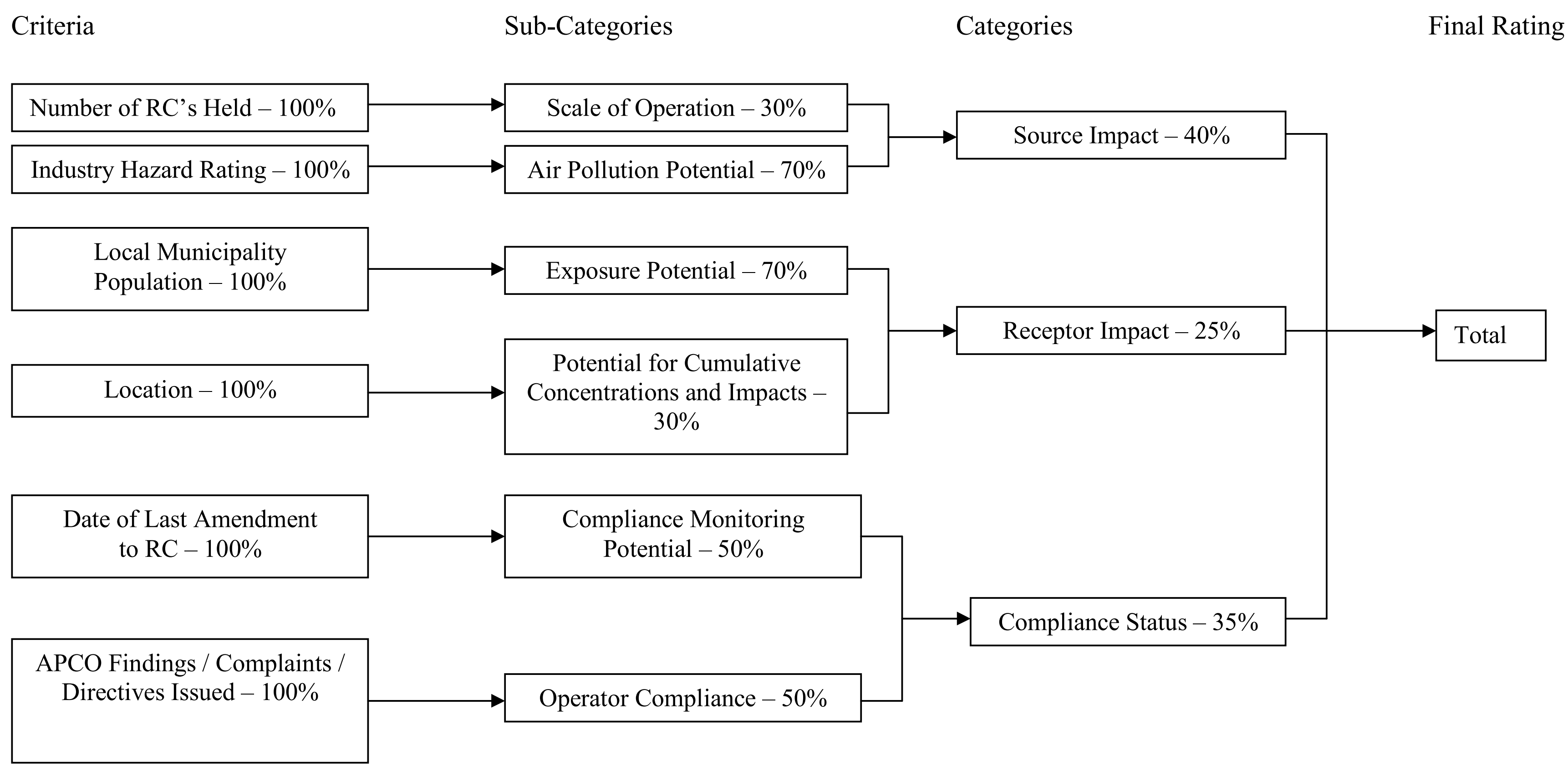

Figure 4.4: **Weightings applied to criteria, sub-categories and categories (after DEAT, 2006c)**

After a score is obtained for a plant it is then aggregated with the other industrial operations within the boundary of the local municipality or metro. This allows for comparison of the industrial emissions on a local, district, provincial and national basis.

4.2.3.2 Mining Sources

Mining operations are considered a significant source of air pollution, specifically dust. Over 70% of copper, 80 % of ferrous metals and 95% of the industrial minerals are mined by surface mines and quarries (Thompson and Visser, 2000). Figure 4.6 shows the percentage contribution to total dust emissions from a typical South African strip mine.

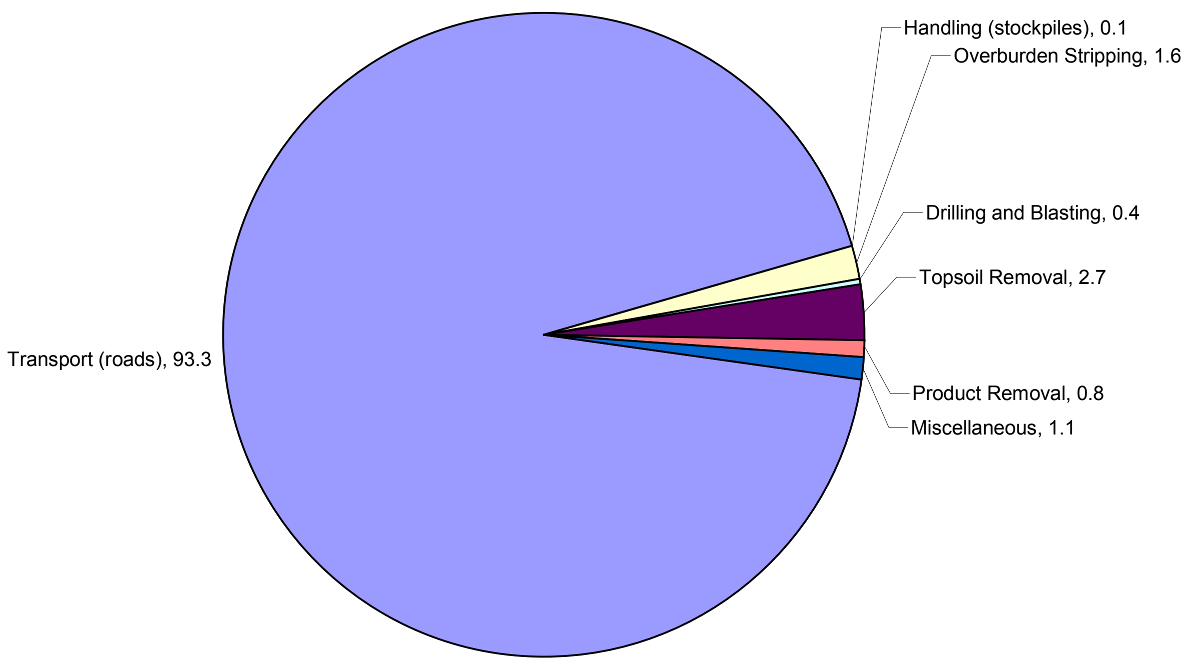

Figure 4.5: Percentage contribution to total dust emissions from typical South African strip mine (after Amponsah-DaCosta, 1997)

Figure 4.6 shows that the haul roads on typical South African strip mines account for over 90% of the dust emissions. The impact of emissions from mining operations may be localised but a high density of mining operations can impact on ambient concentrations. The Department of Mineral and Energy (now the Department of Mineral Resources) publishes a summary of operating mines and quarries and mineral processing plants in South Africa on a regular basis. The most recent summary was published in 2006 (DME, 2006). The report was analysed and all active mines were mapped down to the local government level. Figure 4.7 shows a summary of active mines on a provincial basis. Figure 4.7 shows that the mines are well distributed on a provincial basis, with no single province having more than 15% of the active mines. The DME report includes surface mines, open cast mines, underground mines, mines at sea and mineral beneficiation works. The mines at sea were excluded from the analysis and also the works, whose impact is accounted for in the industrial emissions section.

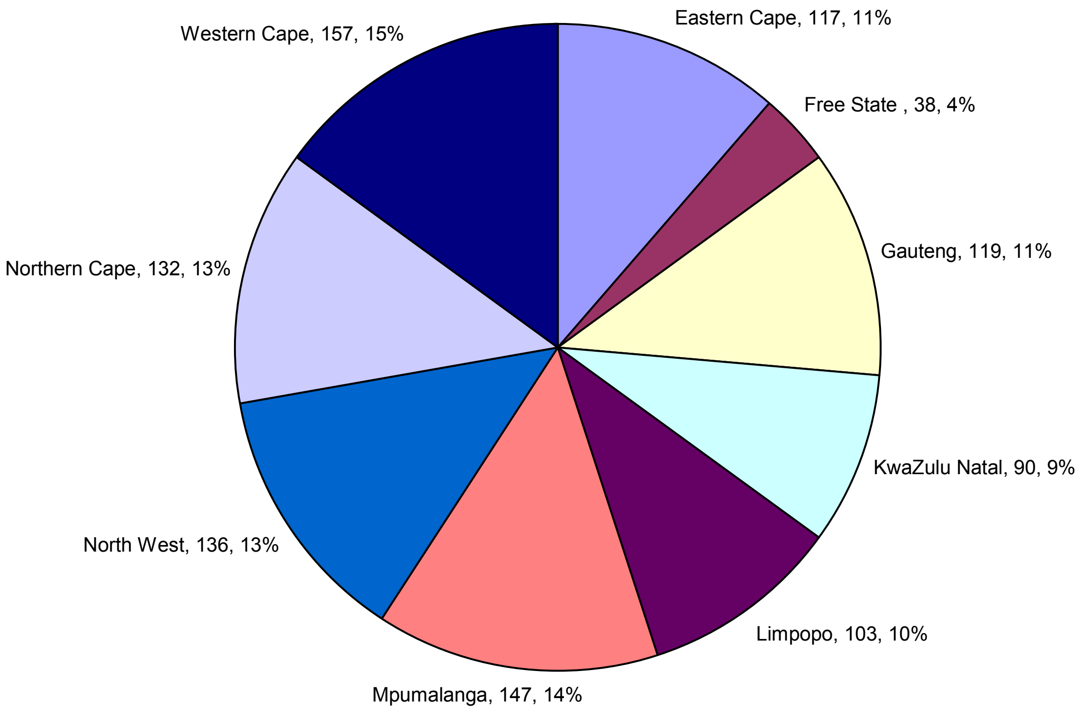

Figure 4.6: Provincial distribution of the active mining operation in South Africa (DME, 2006)

The impact of the mining operations was established by initially calculating the mine density per km^2 across each local municipality. The mine density was then multiplied by the population density of the local municipality to allow for national comparison. The same calculation was applied at the metropolitan and district municipality level. Box 4.2 shows a worked example of the mine impact calculation.

Box 4.2: Worked Examples of Mine Impact Calculation

The Sol Plaatjie Local Municipality is located in the Frances Baard District in the Northern Cape and contains 18 diamond mines within the 1877.1 km^2 area of the local municipality with a population density of 107.3 people/km^2.

Mine density = 18/1877.1 = 0.00958 mines/km^2

Corrected for population density = 0.00958 x 107.3 = 1.029

The Swartland Local Municipality is located in the West Coast District in the Western Cape and contains 21 operational mines within the 3692.2 km^2 area of the local municipality with a population density of 19.5 people/km^2.

Mine density = 21/3692.2 = 0.00569 mines/km^2

Corrected for population density = 0.00569 x 19.5 = 0.111

4.2.3.4 Domestic Sources

Air pollution in dense, low-income settlements in South Africa is acknowledged as a major threat to the health and well-being of people living and working in these communities (Scorgie *et al.*, 2004a; Pauw *et al.*, 2008). Figure 4.8 shows a summary of the results of a FRIDGE study to examine the potential socio-economic impact of measures to reduce air pollution from combustion.

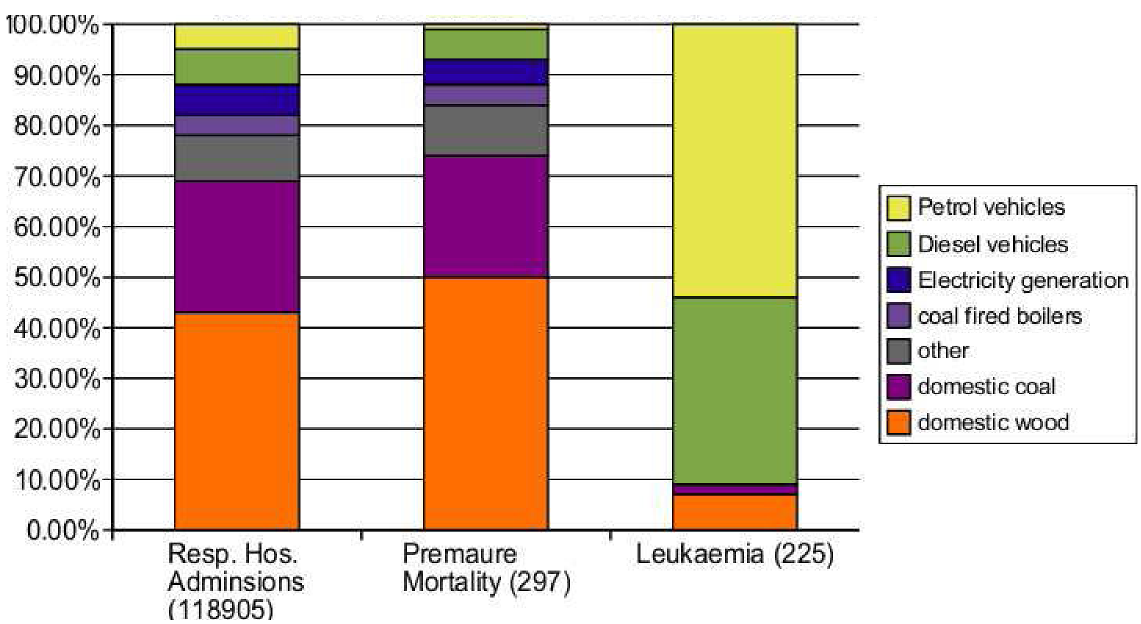

Figure 4.7 Summary of the results of the FRIDGE study (Pauw *et al.*, 2008)

The first column in Figure 4.8 above shows the percentage of respiratory related hospital admissions in relation to the pollution source. Almost 70% of the hospital admissions could be attributed to domestic emissions. The second column in Figure 4.8 shows the percentage of premature mortalities in relation to the pollution source. Over 70% of the premature mortalities could be attributed to domestic emissions.

Domestic air pollution in South Africa is considered to be the single most important source of impact due to the fact that those exposed to the pollution are considered the most susceptible in terms of socio-economic factors (Pauw *et al.*, 2008). They are traditionally the elderly and the youth, with limited finances and limited access to basic health care.

The majority of the dense low-income communities are using energy carriers that are low on the energy ladder (Smith, 1987). The domestic emissions in South Africa can be divided into three categories, emissions from fuels used for space heating, emissions from fuels used for cooking and emissions from fuels used for lighting.

In South Africa, the common fuels used for space heating and cooking include wood, coal and paraffin, with limited use of liquid petroleum gas (LPG) and animal dung. The common fuel used for lighting is paraffin, with limited use of LPG. Candles are also a popular lighting source with limited air pollution impact potential, but the risk of accidental fires is high. Table 4.4 summarises the pollutants emitted by each of the different energy carriers.

Table 4.4 Summary of pollutants emitted by the common energy carriers used in South Africa (Hays et al., 2003; Scorgie *et al.*, 2004b)

Energy Carrier	Associated Pollutants
Coal	Particulate Matter, NO_2, CO, SO_2, PAHs, Heavy Metals and VOCs
Wood	Particulate Matter, NO_2, CO, Polycyclic Aromatic Hydrocarbons (PAHs) and VOCs
Paraffin	Particulate Matter, NO_2, CO and PAHs
LPG	NO_2, CO, SO_2 and VOCs
Other biomass (dung)	Particulate Matter, PAHs, NO_2, CO and VOCs

The Census 2001 data (StatsSA, 2004) for domestic heating, cooking and lighting was analysed on a local municipality level. The dominant carrier was identified for each local municipality. In order to be classified as a dominant carrier more than 25% of the households in the area must be classified as using a particular carrier. This resulted in some cases where more than a single carrier was identified in each area. The carriers or combinations of carriers were rated in terms of their pollution impact potential. Electricity was considered the cleanest carrier, followed by LPG, wood, paraffin and coal (Dockery *et al.*, 1993; Pope III *et al.*, 1995; Brunekreef and Holgate, 2002; Oosthuizen, 2004). No areas were identified where the dominant carrier was other biomass (dung). The carriers or combination of carriers were listed from lowest to highest pollution impact potential. The domestic cooking sector comprised 12 combinations of carriers with electricity rated as one and a combination of wood and coal rated as 12. The domestic heating sector comprised 11 combinations of carriers with electricity rated as one and a combination of wood and coal rated as 11. The domestic lighting sector comprised six combinations of carriers with electricity rated as one and a combination of paraffin and candles rated as six. Following the pollution impact potential rating the scores for each sector were combined to give a single value per local municipality. A weighting was applied to each activity based on the scale of the emissions potential. Cooking and heating consume more fuel than that used for lighting. For the average household with an income under R 3000 per month, 60% of monthly energy expenditure was used on cooking, 30% on space heating and 10% on lighting (Winkler *et al.*, 2002). The same weighting was applied to each sector to derive a single value per local municipality. In order to account for the impact of dense highly populated areas the final domestic emission rating was then multiplied by the population density. Box 4.3 provide a worked example of the rating and weighting system

This methodology differs from the conventional approach to domestic emission estimations, which applies emission factors to estimated fuel usage to estimate actual emissions (EMM, 2004; Scorgie *et al.*, 2004b; DEAT, 2007b). The high degree in variability of the fuel quality creates a degree of uncertainty in the results produced by this methodology, combined with the uncertain impact of the national electrification programme. Pauw *et al.* (2008) indicate that the trends in domestic energy sources are changing, as such, until the next full population census scheduled for 2011, the emission estimates from this sector will carry a high degree of uncertainty.

Box 4.3: Worked Example of the Domestic Emission Rating and Weighting System

Urban Example

In the Nelson Mandela Bay Metropolitan Municipality the dominant energy carriers for domestic cooking are electricity and paraffin, while the dominant energy carriers for domestic heating are electricity and paraffin and the dominant energy carrier for lighting is electricity.

The pollution impact potential rating for electricity / paraffin for cooking is 3 (Weighting – 60%) = 1.8

The pollution impact potential rating for electricity / paraffin for heating is 2 (Weighting – 30%) = 0.6

The pollution impact potential rating for electricity for lighting is 1 (Weighting – 10%) = 0.1

Final domestic emission rating = 1.8+0.6+0.1 = 2.5

Corrected for population density - 2.5 x 513.4 = 1283.5

Rural Example

In the Engcobo Local Municipality the dominant energy carrier for domestic cooking is wood, while the dominant energy carrier for domestic heating is wood and the dominant energy carriers for lighting are paraffin and candles.

The pollution impact potential rating for wood for cooking is 6 (Weighting – 60%) = 3.6

The pollution impact potential rating for wood for heating is 5 (Weighting – 30%) = 1.5

The pollution impact potential rating for paraffin / candles for lighting is 6 (Weighting – 10%) = 0.6

Final domestic emission rating = 1.8+0.6+0.1 = 5.7

Corrected for population density – 5.7 x 65.7 = 374.5

4.2.3.5 Summary of Air Pollution Impact Potential Impact

Each emission parameter will be individually mapped at a district and local municipality level on a national basis. The rating for each sector will be derived based on the following methodology. Population density will be rated on a seven level scale for both the district and local municipality level, with one indicating a low population density. The industrial emission impact will be rated on a six level scale for the district municipalities and a nine level scale for the local municipalities, with one indicating a low industrial emission impact potential. The mining impact will be rated on a six level scale for both the district and local municipality level, with one indicating a low impact potential. The traffic emission impact will be rated on a six level scale for both the district and local municipality level, with one indicating a low traffic emission impact potential. The domestic impact will be rated on a seven level scale for both the district and local municipality level, with one indicating a low domestic impact potential. These parameters were then combined to produce a single score for each district and local municipality. Since most of these parameters have been corrected based on population density and area, each of the ratings will carry equal weight. The district municipalities were rated on a scale of five to 32, while the local municipalities were rated on a scale ranging from five to 35, with five indicating a low air pollution impact potential, increasing to the respective maximums.

4.2.4 Topography

The topographical component of the analysis will only be applied after the primary analysis of the geopolitical boundary, population density and emission analysis. The New Zealand methodology describes an extremely complicated methodology for ridge analysis and the identification of potential airsheds (Fisher *et al.*, 2005). The methodology used in this research will be the overlaying of the four major catchment categories (primary, secondary, tertiary and quaternary) as identified by the Department of Water Affairs and Forestry (now Department of Water Affairs). The topography analysis will be used to decide whether two adjacent municipalities should be considered as separate air quality management areas or whether the topography of the area indicates that two or more adjacent areas should be combined into a single air quality management area. Figure 4.9 shows the location of the four different catchment types in South Africa. The tertiary and quaternary catchment levels are considered to be too detailed for an assessment at the district and local municipality level, as such only the primary and secondary catchment levels will be used in the topographical analysis.

4.3 Spatial Analysis

Each of the components will be captured into a GIS. The GIS will then overlay each of the components to produce a composite air pollution impact potential rating for each metro / district / local municipality. No adjustments to the standard operation of the GIS technique were applied. The analysis of the results will involve an assessment of the location of the existing national priority areas, the potential identification of additional national priority areas, the potential identification of provincial priority areas and a comparison with the municipalities listed in Table 24 of the National Framework.

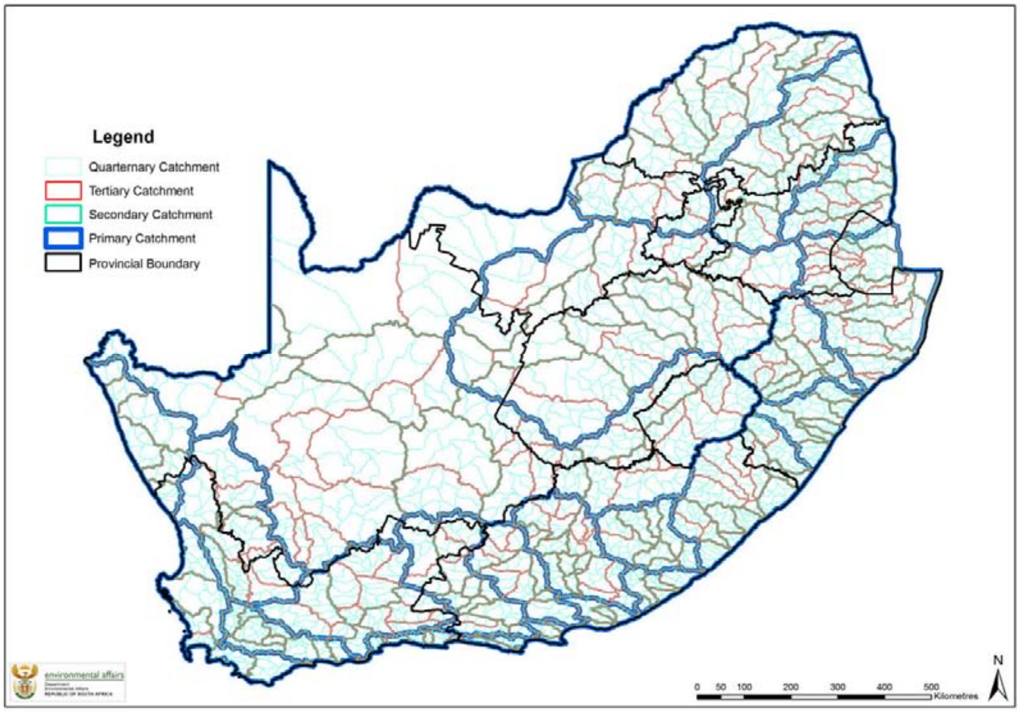

Figure 4.8 Location of the boundaries of the four major catchment types in South Africa (after DWA, 2009)

CHAPTER FIVE
RESULTS

5.1 Introduction

The results are provided at the district and local municipality level, with both incorporating the metropolitan municipalities. The district and metropolitan municipalities are the future atmospheric emission licencing authorities and will form the primary level of assessment when identifying the boundaries of air quality management areas, however the results at the local municipality level allow for the refinement of boundaries of the areas.

5.2 Population Density

Figure 5.1 shows the population density for South Africa at the district and metropolitan municipality level. As expected, the highest population densities are indicated in the six metropolitan municipalities. The national average population density is 36.7 people/km^2. The Gauteng province has the highest population density (493.3 people/km^2), with over 20% of the total population of the country located within only 2% of the total surface area. The Northern Cape province has the lowest population density (3.7 people/km^2), with only 2% of the total population located within 24% of the total surface area. Table 5.1 summarises the population density per province. The population density in the eastern half of the country is higher than the western half. KwaZulu-Natal, Limpopo and the Eastern Cape have relatively high population densities outside of the major urban centres.

Table 5.1: Summary of population density per province

Province	Population Density (people/km^2)
Eastern Cape	40.9
Free State	20.9
Gauteng	493.3
KwaZulu Natal	106.1
Limpopo	43.2
Mpumalanga	51.3
North West	28.5
Northern Cape	3.7
Western Cape	44.7

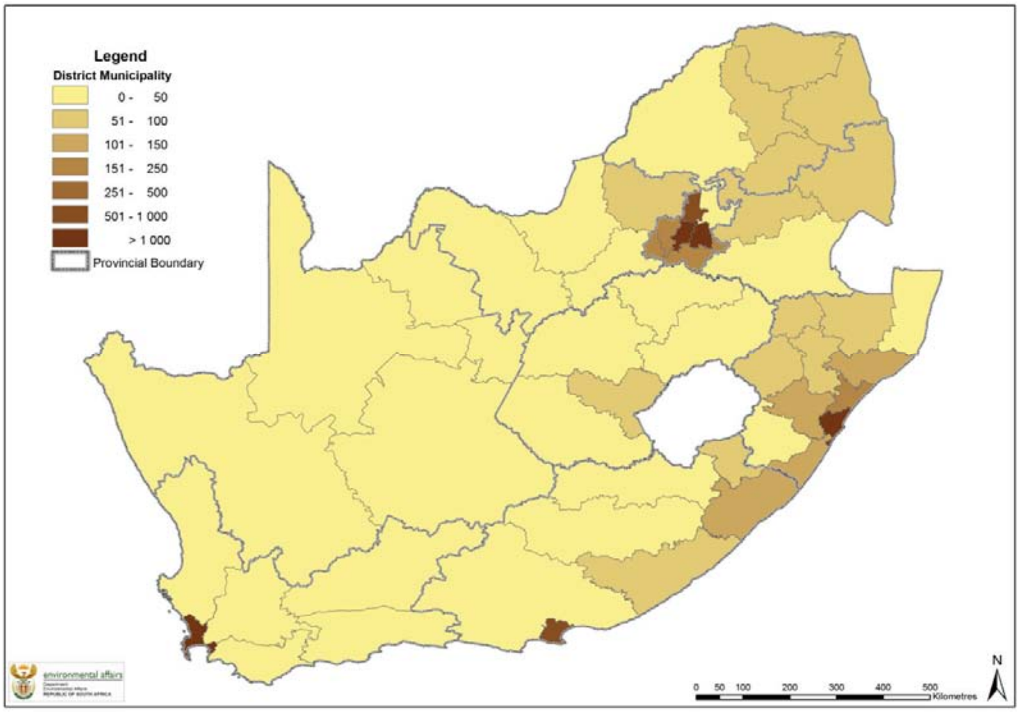

Figure 5.1 Population densities (people/km^2) by district municipality

Figure 5.2 shows the population density for South Africa at the local municipality level. The grey areas are district management areas (DMAs) which are the formally declared nature conservation areas. The population densities in these areas are very low due to the low number of permanent residents and have been excluded from this study. The local municipality with the lowest population density (0.4 people/km^2) is the Karoo Hoogland Local Municipality in the Northern Cape, while the local municipality with the highest population density (872.9 people/km^2) is the Msunduzi Local Municipality in KwaZulu-Natal. Figure 5.2 again shows the high population densities in the eastern half of the Eastern Cape, the central and eastern areas of Limpopo and throughout KwaZulu-Natal. These areas are predominately rural and the relatively high population densities can be attributed to the apartheid legacy of independent homelands, namely Transkei, Bophuthatswana, Ciskei, Venda, Gazankulu, Lebowa and KwaZulu. This figure also shows the location of the larger urban centres, namely Bloemfontein, Kimberley, Pietermaritzburg, Nelspruit and East London.

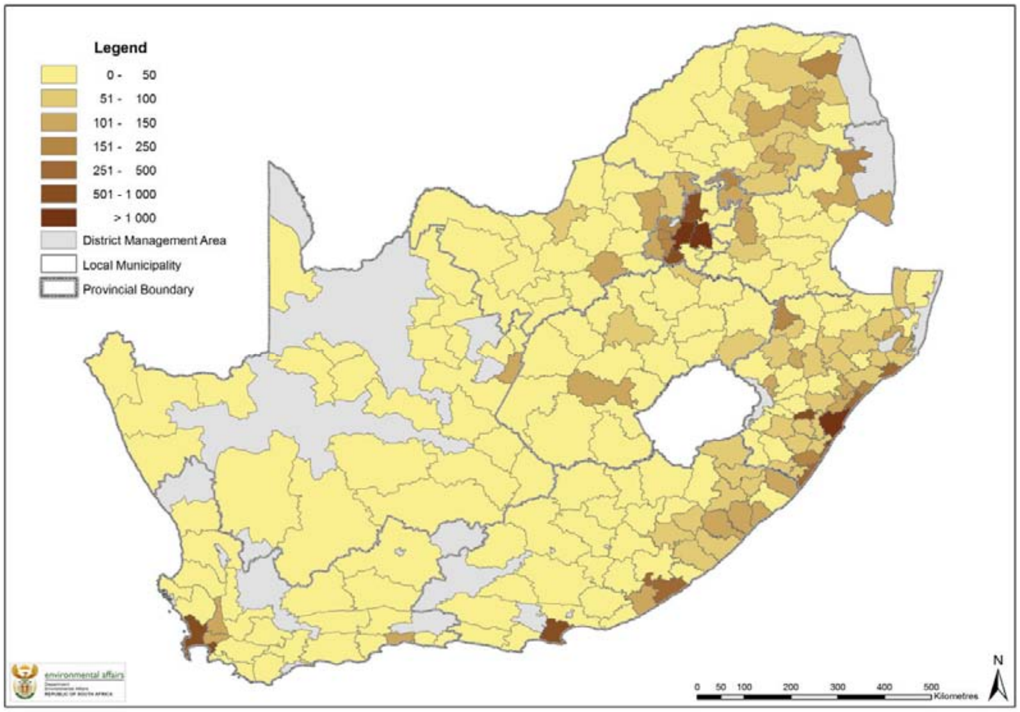

Figure 5.2 Population densities (people/km^2) by local municipality

5.3 Emissions

5.3.1 Industrial Sources

The industrial source results are presented in two separate ways. Firstly the actual number of companies operating scheduled processes is presented at both the district and local municipality level. This is followed by the industrial impact rating, also at the district and local municipality level. Figure 5.3 shows the number of companies operating scheduled processes at the district and metropolitan municipality level.

The Gauteng province has the highest number of companies registered in terms of the APPA, with 486 or 33% of the national total. The Northern Cape province has the fewest companies registered, with only 30 or 2% of the national total. Outside of the metropolitan municipalities the Bojanala Platinum (North-West), Gert Sibande (Mpumalanga), Nkangala (Mpumalanga) and Ehlanzeni (Mpumalanga) District Municipalities have the highest number of companies registered.

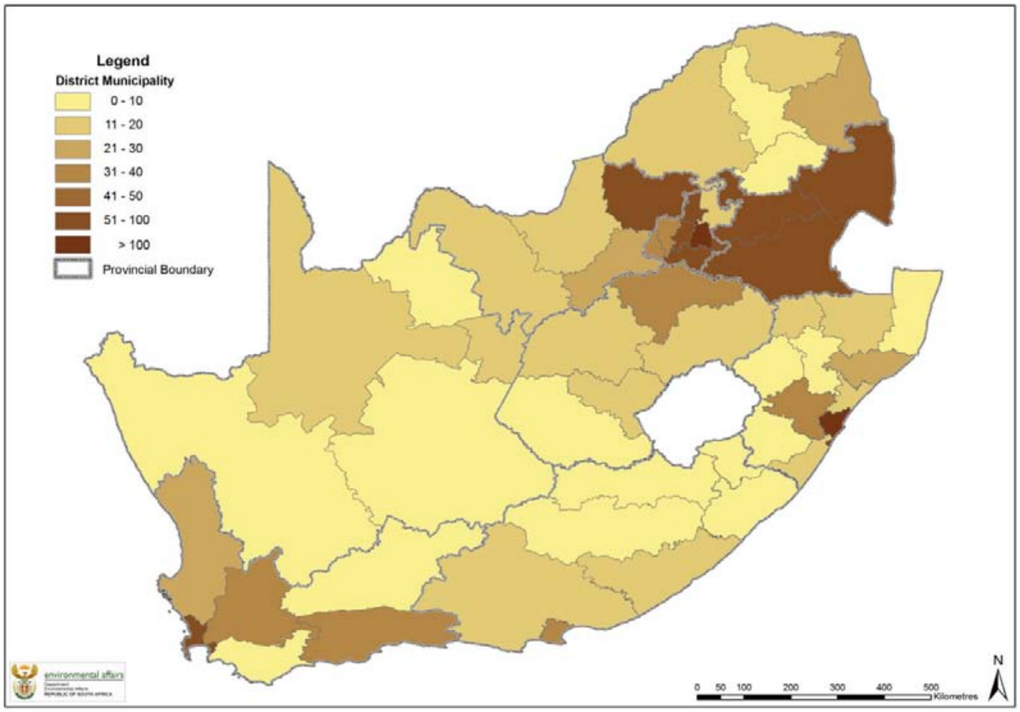

Figure 5.3 Summary of the number of companies operating scheduled processes by district municipality

The establishment of an atmospheric emission licencing authority requires extensive human, financial and technical resources. As such, the DEA is recommending that all licencing authorities with 10 or fewer companies should consider delegating the licencing responsibility to the relevant province in terms of Section 36 of the AQA. Based on the information presented in Figure 5.3, all of the metropolitan municipalities should undertake the atmospheric emission licencing function, 16 of the district municipalities should consider delegating the function to the respective provinces, while the remaining 34 district municipalities should considering offering the atmospheric emission licencing function. A more detailed analysis will be provided in Chapter 6.

Figure 5.4 shows the number of companies operating scheduled processes at the local and metropolitan municipality level. The Ekurhuleni Metro has the highest number of individual companies, 234 or 15.5% of the national total. The Emalaheni Local Municipality (Mpumalanga) has the highest number of individual companies at the local municipality level, 36 or 2.3% of the national total.

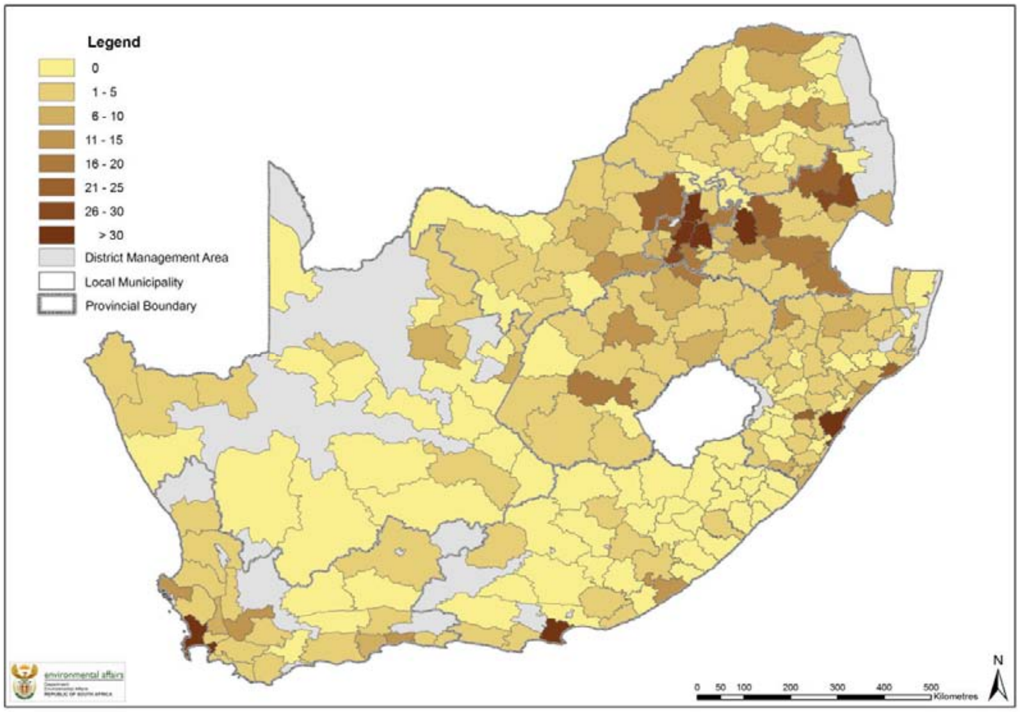

Figure 5.4 Summary of the number of companies operating scheduled processes by local municipality

Figure 5.4 shows that many local municipalities in the Northern Cape, Limpopo and Eastern Cape do not have a single company registered. A detailed summary of metropolitan, district and local municipality information is provided in Appendix 1.

Figure 5.5 shows the industry rating at the metropolitan and district municipality level following the application of the rating methodology described in Section 4.2.3.1. The rating methodology is applied to each individual company and this is then agglomerated at the local, district and metropolitan municipality level. This information is considered to be more representative of the air pollution impact potential of each of the sites. When compared with Figure 5.3, a similar pattern emerges. However, the low rating score by smaller industrial operations in the more rural areas of the Northern Cape, KwaZulu-Natal and Eastern Cape is apparent. The high impact rating in Mpumalanga confirms the previous observations made in Figure 5.3. This parameter will be used as the input to represent industrial sources in the air pollution impact potential indicator value.

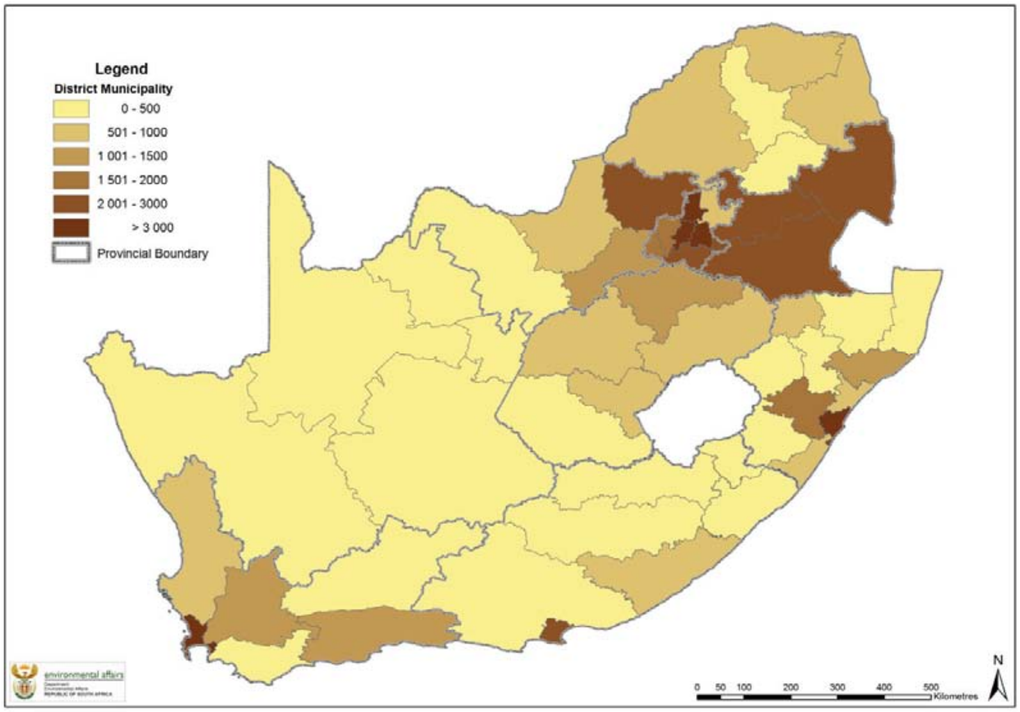

Figure 5.5 Summary of industry rating of companies operating scheduled processes by district municipality

Figure 5.6 shows the industry rating at the local municipality level. The results confirm the observations made from Figure 5.4, with the highest air pollution impact potential from industrial emissions occurring in the metropolitan municipalities. In the Eastern Cape, the Buffalo City Local Municipality is the only area outside of the Nelson Mandela Bay Metro that indicates high air pollution impact potential (rating greater than 500). This can be attributed to the industrial activity in the city of East London. In the Free State, three local municipalities are highlighted as having high air pollution impact potential, namely Metsimaholo, Matjhabeng and Manguang. This can be attributed to the industrial activity in the towns of Sasolburg and Welkom and the city of Bloemfontein, respectively. In Gauteng there are four local municipalities outside of the metros that are highlighted as having high air pollution impact potential. They include Emfuleni, Midvaal, Mogale City and Kungwini. This can be attributed to the industrial activity in the towns of Vanderbijlpark, Vereeniging, Krugersdorp and Bronkhorstspruit, respectively. In KwaZulu-Natal there are three local municipalities outside of the Ethekwini Metro that are highlighted as having high air pollution impact potential, they include uMhlathuze, Umsunduzi and Newcastle. This can be attributed to the industrial activity in the cities of Richards Bay and Pietermaritzburg and the town of Newcastle, respectively. There are no local municipalities in the Limpopo Province identified as having high air pollution impact potential due to industrial emissions.

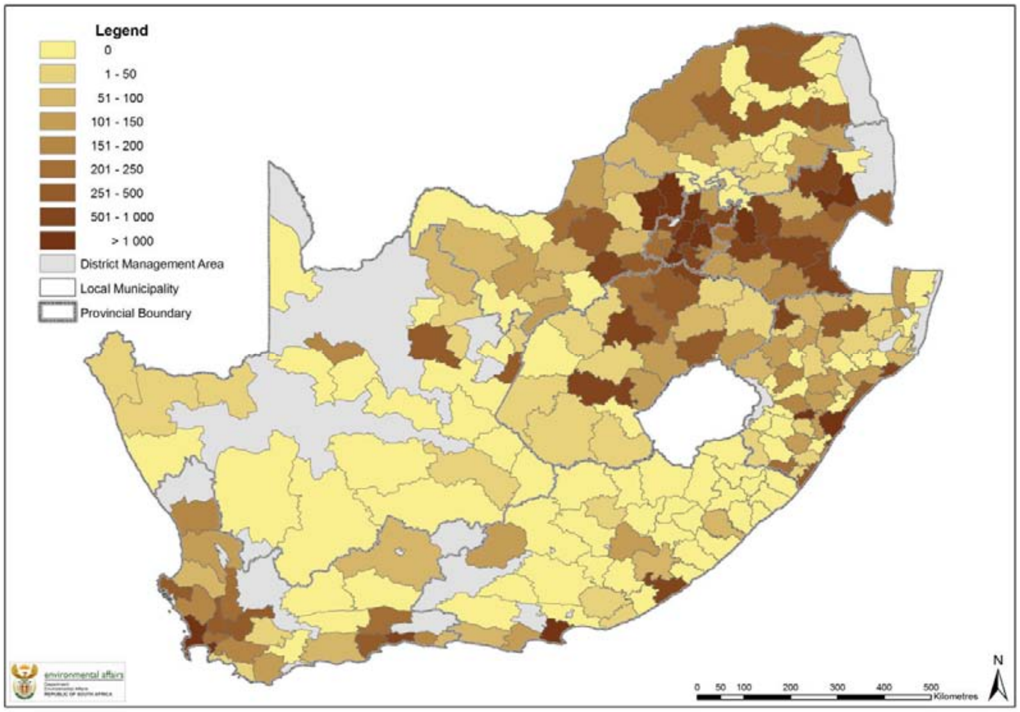

Figure 5.6 Summary of industry rating of companies operating scheduled processes by local municipality

In Mpumalanga there are seven local municipalities that are highlighted as having high air pollution impact potential, they include Msukaligwa, Mkhondo, Govan Mbeki, Emalahleni, Steve Tshwete, Mbombela and Thaba Chweu. In the North-West there are two local municipalities identified as having high air pollution impact potential, they include Madibeng and Rustenburg. This can be attributed to the industrial activity in the towns of Brits and Rustenburg respectively. There are no local municipalities in the Northern Cape identified as having high air pollution impact potential due to industrial emissions. In the Western Cape there is only one local municipality, outside of the City of Cape Town Metro, that is identified as having high air pollution impact potential due to industrial emissions, namely the George Local Municipality.

5.3.2 Mining Sources

Figure 5.7 shows the density of mining operations on a metropolitan and district municipality scale. There is a high density of coal mines in the Gert Sibande and Nkangala District Municipalities in Mpumalanga. There is a high density of platinum group metal (PGM) mines in the Bojanala Platinum District Municipality in the North-West. There is a high density of diamond mines in the Frances Baard District Municipality in the Northern Cape.

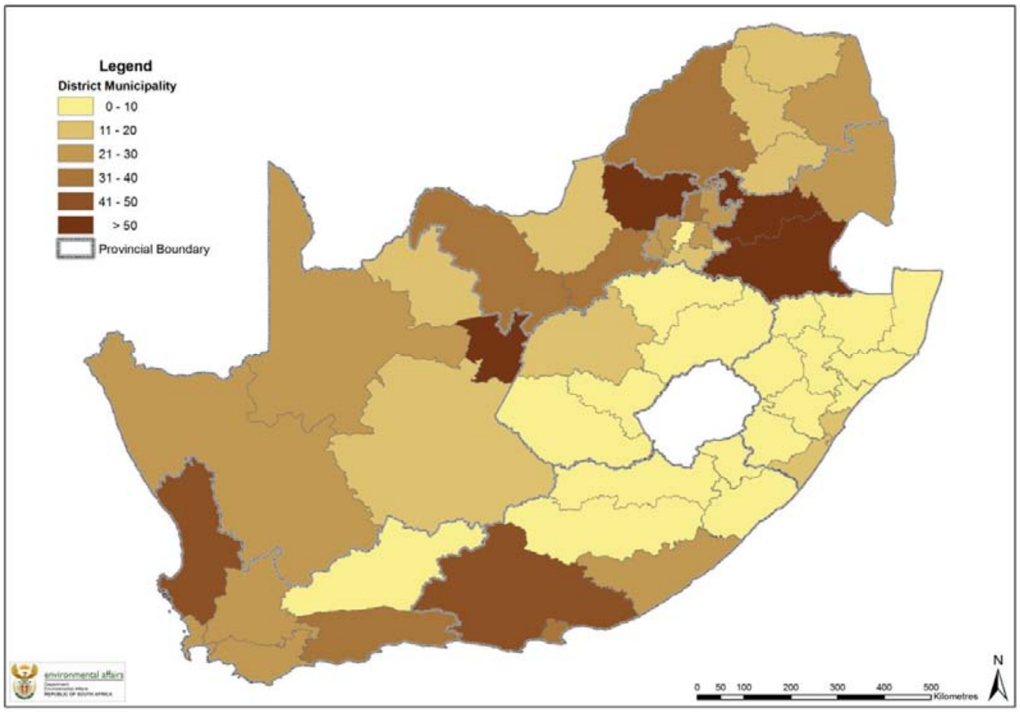

Figure 5.7 Summary of the number of operational mines by district municipality

The high density of mines in the Cacadu and West Coast District Municipalities are associated with quarrying activities for the production of aggregate and crusher sand, while sand mining and clay mining also occurs in these areas. Mining activities appear to be concentrated in the northern and western parts of the country, with relatively fewer mines in the north of the Eastern Cape, the Free State and KwaZulu-Natal.

Figure 5.8 shows the density of mines on a local municipality scale. Over 35% of the local municipalities do not have a single active mine within their jurisdiction. There is a high density of mining operations in the vicinity of the metropolitan areas, mostly to provide quarry material for construction purposes. The local municipality with the highest number of mines (40) is the Dikgatlong Local Municipality in the Northern Cape where diamond mining dominates.

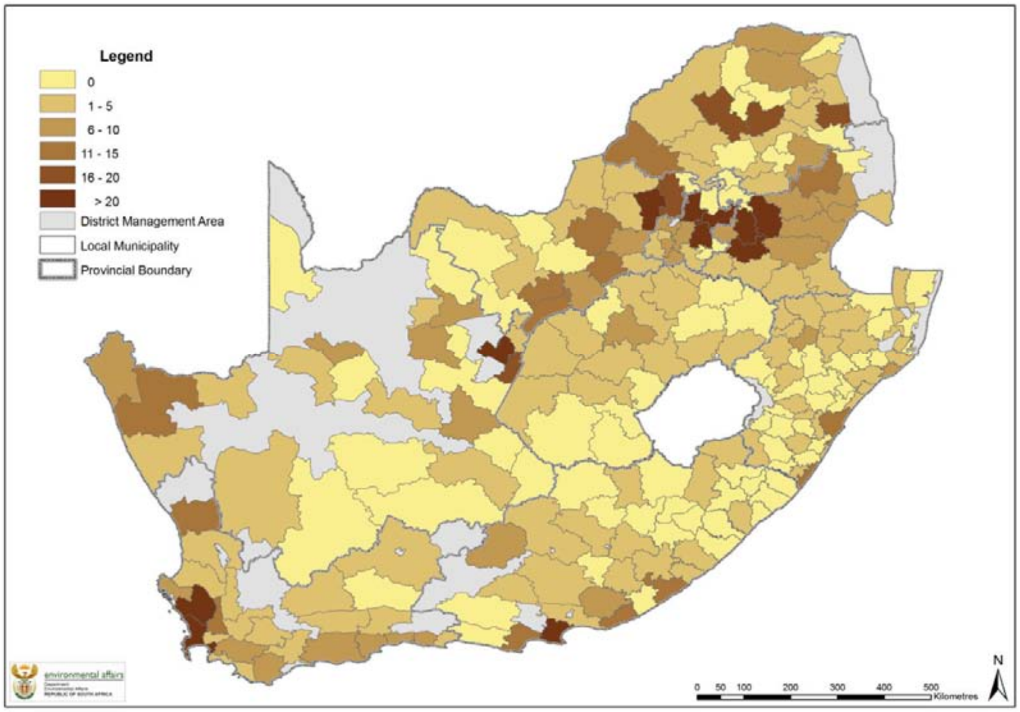

Figure 5.8 Summary of the number of operational mines by local municipality

Figure 5.9 shows the mining rating at the metropolitan and district municipality level following the application of the methodology described in Section 4.2.3.2. The rating methodology is applied at each local government structure level. This rating system is considered to be more representative of the air pollution impact potential of mining operations in each area.

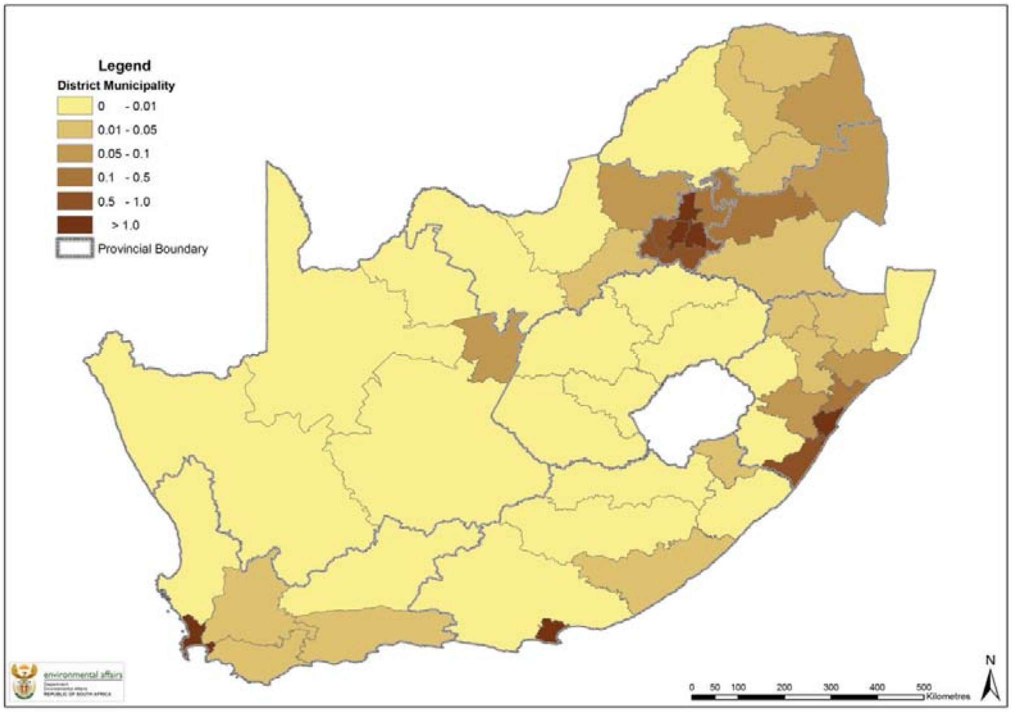

Figure 5.9 Summary of the mining rating by district municipality

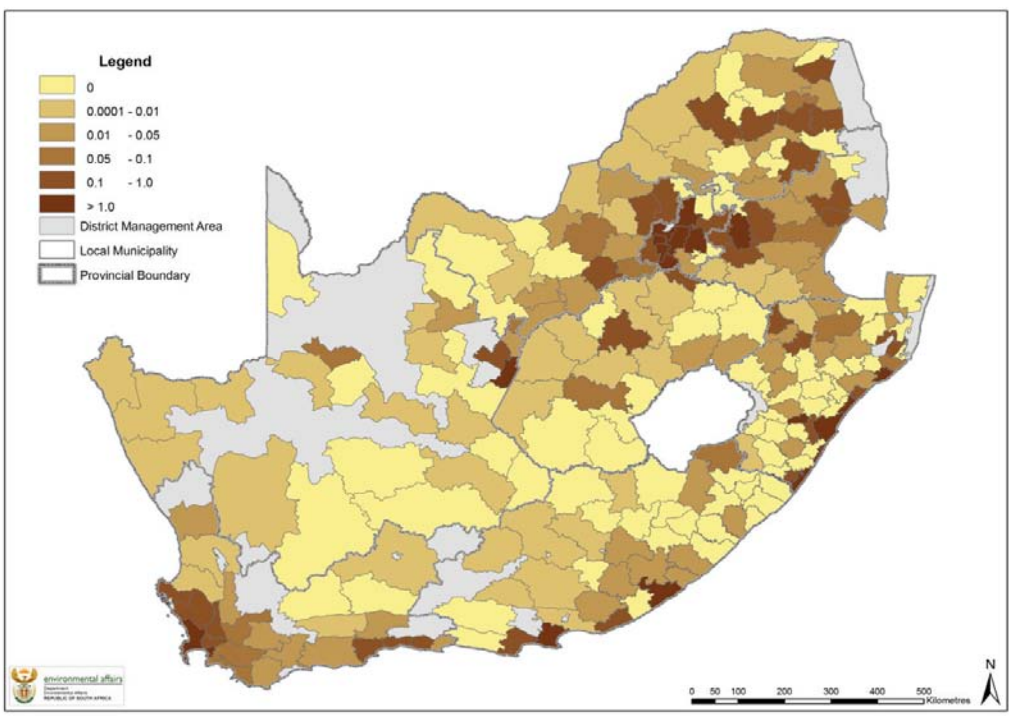

Figure 5.10 Summary of the mining rating by local municipality

There are discernable differences between the maps indicating the mine density and those which have been corrected for population density. At the district municipality level (Figures 5.7 & 5.9) the areas of high mine density and low population density are apparent in the Northern Cape, Limpopo and Mpumalanga. The areas of lower mine density but high population density are apparent in Gauteng and KwaZulu Natal. These observations are further amplified by the maps showing the local municipality level (Figures 5.8 & 5.10).

5.3.3 Domestic Sources

Figures 5.11 and 5.12 show the summary of the domestic emission potential at the metropolitan and district and local municipality level, respectively. It is apparent that the eastern half of the country has a higher domestic emissions potential than the western half. This can also be attributed to the fact that the calculation takes population density into consideration. While electricity is widely used in the metropolitan municipalities, the dense low income settlements found throughout these areas contribute to the high domestic emissions potential.

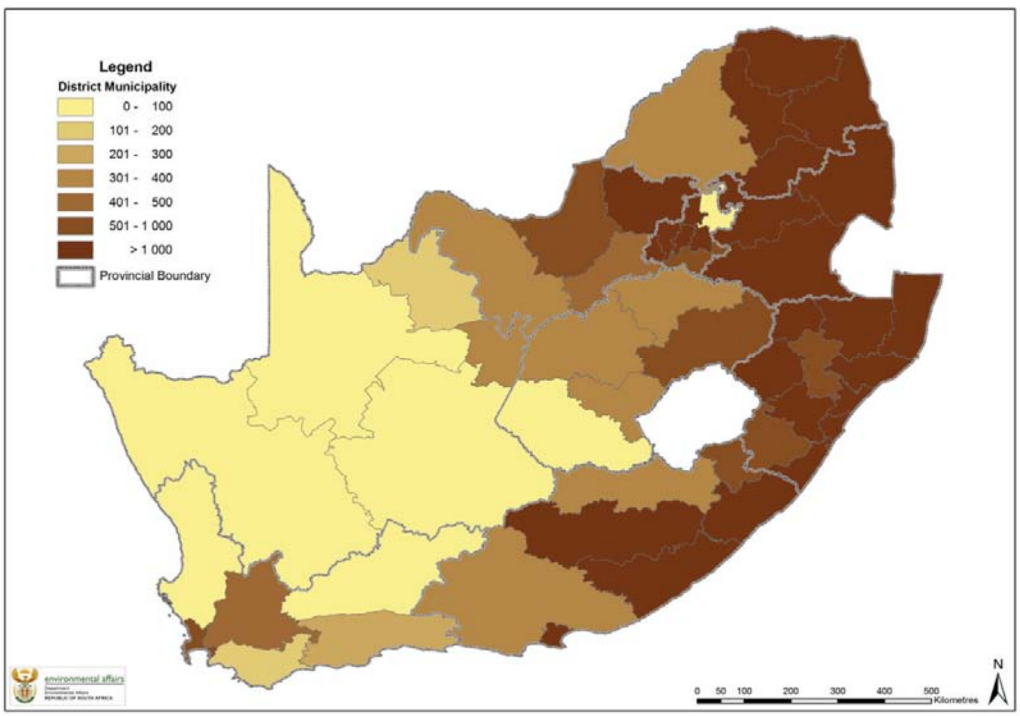

Figure 5.11 Summary of domestic emissions potential by district municipality

The dominant fuel used for cooking in urban areas is paraffin, while wood and coal are used to a lesser extent. The dominant fuel use for cooking in rural areas is wood. Electricity and wood are the common fuels used for space heating, with paraffin used to a lesser extent. Coal usage is more commonly used in the interior of the country and more specifically in the areas close to the coal mines, namely Mpumalanga and northern KwaZulu-Natal. The dense rural populations using coal and wood for cooking and heating purposes are clearly visible in Limpopo, KwaZulu-Natal, Mpumalanga and the Eastern Cape. Surprisingly, the Western Cape is heavily reliant on electricity, even in rural areas.

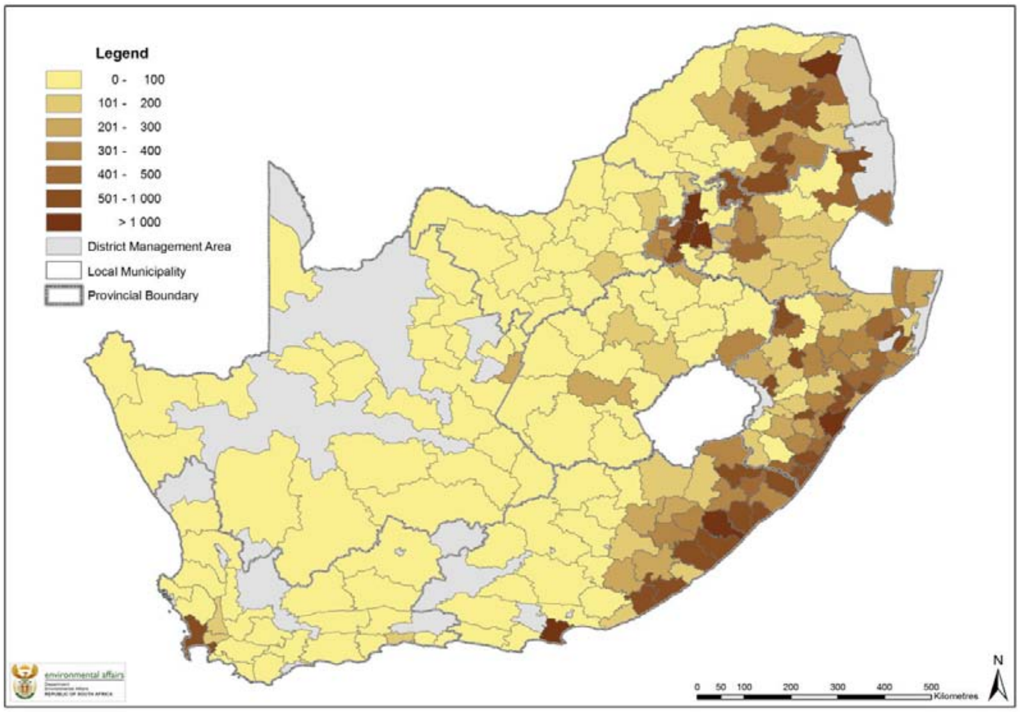

Figure 5.12 Summary of the domestic emission potential by local municipality

5.4 Air Pollution Impact Potential Rating

Each of the parameters presented above was combined into a single air pollution impact potential rating by municipality. Box 5.1 provides worked examples for the calculation of three separate air pollution impact potential rating calculations. Figure 5.13 and 5.14 shows the air pollution impact potential rating for the district and local municipalities respectively. The higher the rating value the higher the air pollution impact potential. All of the metropolitan municipalities have high air pollution impact potential ratings. Each of these maps will be subjected to topographical analysis, after which the delineation of air quality management areas within South Africa will be determined.

Box 5.1 Worked example of air pollution potential impact rating calculations

High Impact Potential Rating

The Nelson Mandela Bay Metropolitan Municipality (Port Elizabeth) in the Eastern Cape has a population density of 513.4 people/km^2 which resulted in a rating of six on the seven level scale. The area has 40 companies operating scheduled processes and scored an industrial impact of 2224.2 which resulted in a rating of five on the six level scale. The area has 38 operational mines and scored a mining impact ratio of 9.96 which resulted in a rating of six on the six level scale. The area scored a domestic rating of 1206.5 which resulted in a rating of seven on a seven level scale.

Final rating = 6+5+6+7 = 24 out of a possible 26

Medium Impact Potential Rating

The Mopani District Municipality in Limpopo has a population density of 86.9 people/km^2 which resulted in a rating of two on the seven level scale. The area has 21 companies operating scheduled processes and scored an industrial impact of 897.0 which resulted in a rating of two on the six level scale. The area has 21 operational mines and scored a mining impact ratio of 0.16 which resulted in a rating of four on a six level scale. The area scored a domestic rating of 1864.4 which resulted in a rating of seven on a seven level scale.

Final rating = 2+2+4+7 = 15 out of a possible 26

Low Impact Potential Rating

The Xhariep District Municipality in the Free State has a population density of 3.9 people/km^2 which resulted in a rating of one on the seven level scale. The area has 3 companies operating scheduled processes and scored an industrial impact of 109.1 which resulted in a rating of one on the six level scale. The area has 1 operational mine and scored a mining impact ratio of 0.0001 which resulted in a rating of one on a six level scale. The area scored a domestic rating of 45.1 which resulted in a rating of one on a seven level scale.

Final rating = 1+1+1+1 = 4 out of a possible 26

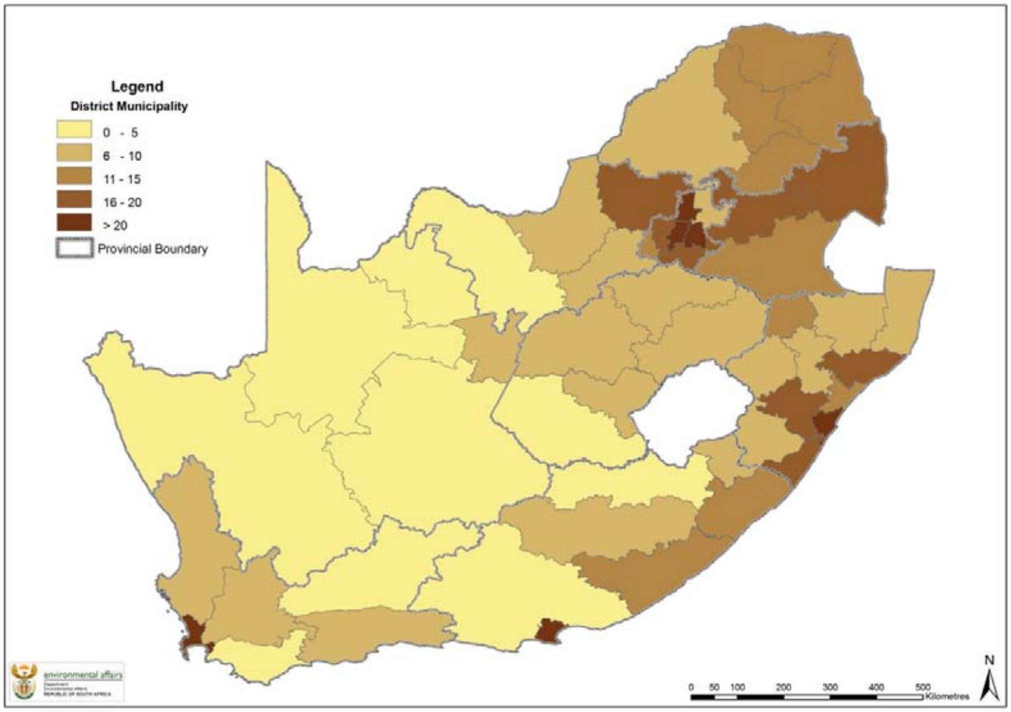

Figure 5.13 Air pollution impact potential rating for district municipalities

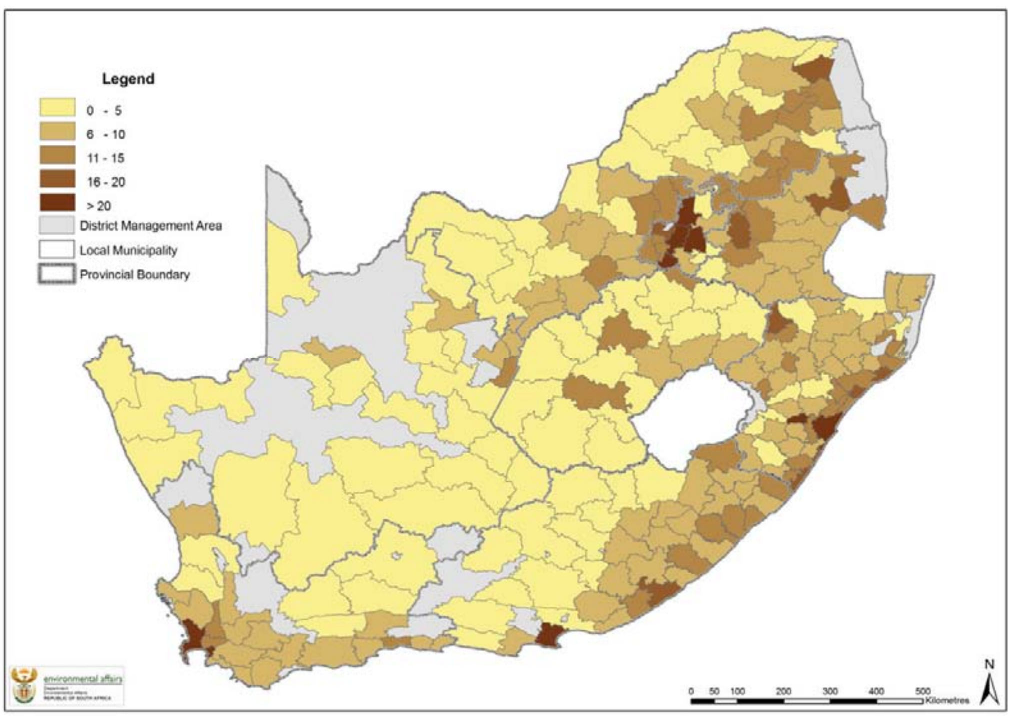

Figure 5.14 Air pollution impact potential rating for local municipalities

5.5 Topographical Analysis

Topography is the final parameter that will be used in the methodology to delineate the boundary of air quality management areas in South Africa. The Department of Water Affairs has defined all the river catchments in South Africa, at the primary, secondary, tertiary and quaternary level (DWA, 2009). The final air pollution impact potential maps will be overlain with the primary and secondary river catchments which have been shown to be the most appropriate levels to be used in the topographical analysis. Figure 5.15 shows the district municipality air pollution impact potential map with the primary and secondary river catchments. Figure 5.16 shows the local municipality air pollution impact potential map with the primary and secondary river catchments.

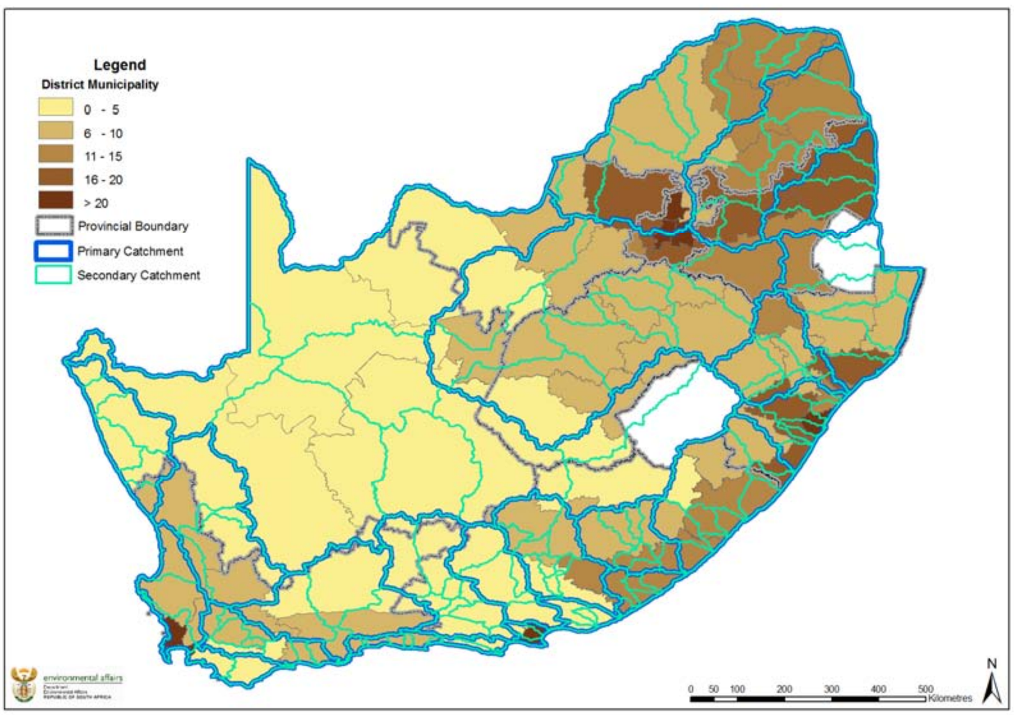

Figure 5.15 Primary and secondary river catchments in relation to district municipalities

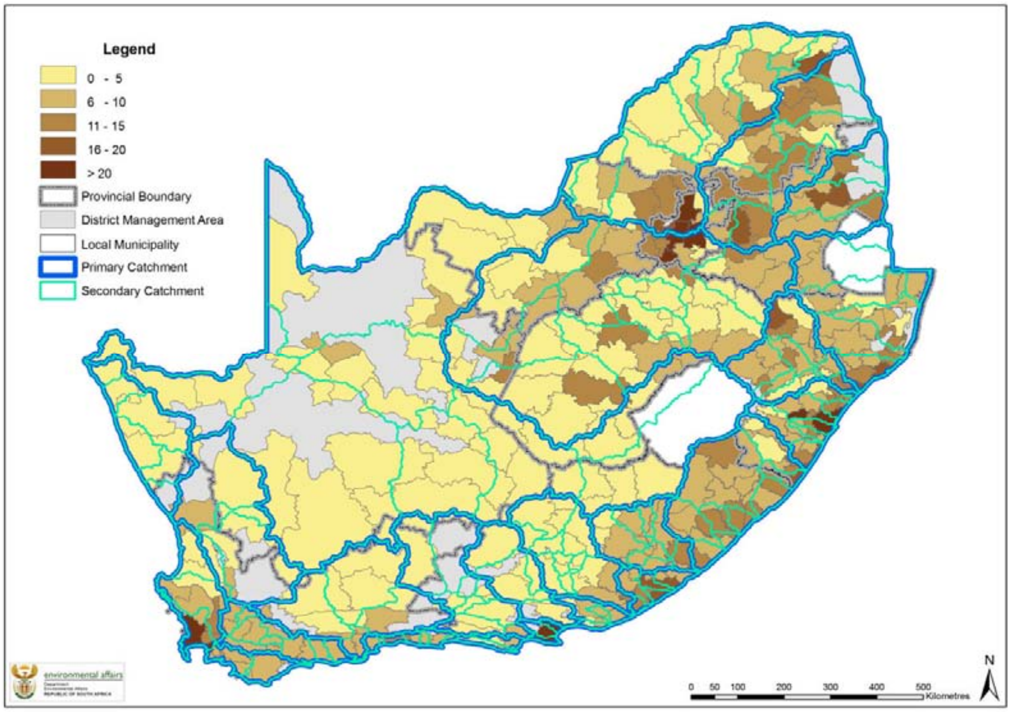

Figure 5.16 Primary and secondary river catchments in relation to local municipalities

The primary river catchments and district municipalities have been used for the preliminary assessment of the boundaries of air quality management areas, this will be further refined through the use of secondary river catchments and local municipalities in Chapter 6.

CHAPTER 6

DISCUSSION AND IMPLICATIONS FOR GOVERNMENT

6.1 Introduction

The AQA makes provision for the introduction of the priority area management tool as a mechanism to address areas where the ambient air quality exceeds or is likely to exceed ambient standards. Since air pollution may have cross-boundary impacts and air quality management resources in South Africa are limited, cooperation between the different spheres of government is required (Scorgie *et al.*, 2004a; Zunckel *et al.*, 2006a; Piekth *et al.*, 2006). Three different types of priority areas can be designated, each with their own criteria and management implications.

In the event an air quality management area crosses a provincial or national boundary, then the Minister must declare a national priority area. The National Air Quality Officer (NAQO) takes responsibility for the development and implementation of the national priority area management plan, together with all the other affected spheres of government. In the event an air quality management area crosses a district or metropolitan boundary, but remains within a single province, then the MEC must declare a provincial priority area. The Provincial Air Quality Officer (PAQO) takes responsibility for the development and implementation of the provincial priority area management plan. Should the province not have sufficient capacity to assume responsibility for the priority area, then the MEC may request the Minister to take responsibility for the development and implementation of the provincial priority area management plan. Should an air quality management area fall within a single district or metropolitan municipality, then the air quality management plan for that district or metropolitan municipality must address the problem.

The results from Chapter 5 will now be assessed at the national, provincial and local government level. At the national level, two national priority areas have been declared to date. An assessment will be undertaken to check whether the declarations were justified and the extent to which the boundaries of the areas, which were subjectively determined, coincide with boundaries as determined by the methodology developed through this research. A further investigation will be done to see whether any other areas in the country warrant declaration as national priority areas. To date, no provincial priority areas have been declared in South Africa. A preliminary assessment will be undertaken to identify any potential provincial priority areas. Finally, an assessment will be undertaken to assess the justification of the classification of the local municipalities identified in Table 24 of the National Framework.

6.2 National Implications

6.2.1 Vaal Triangle Airshed Priority Area

Figure 6.1 shows the extent of the Vaal Triangle Airshed Priority Area (VTAPA) that was declared on 21 April 2006. The area covers portions of the Gauteng and Free State Provinces. District or metropolitan municipalities involved includes the City of Johannesburg, Sedibeng and Fezile Dabi, while local municipalities involved include Emfuleni, Midvaal and Metsimaholo. The VTAPA includes the historical Vaal Triangle, defined as the area within the towns of Sasolburg, Vanderbijlpark and Vereeniging (Terblanche *et al.*, 1992), with an extended area towards the north, including the southern regions of the City of Johannesburg.

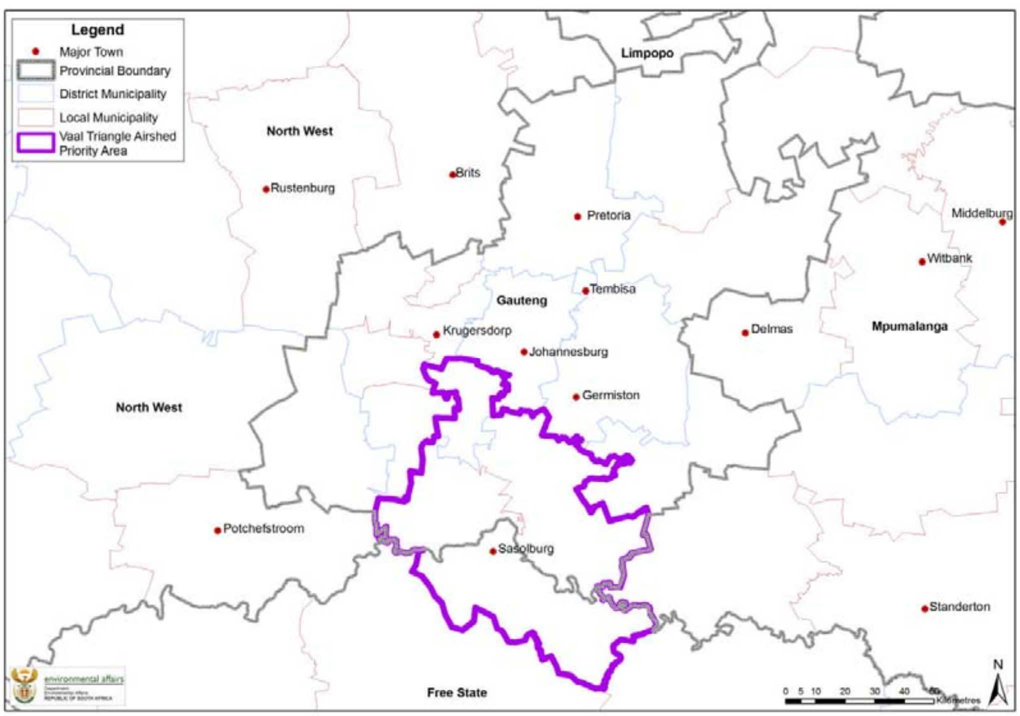

Figure 6.1 Extent of the Vaal Triangle Airshed Priority Area

Figures 6.2 and 6.3 shows the results of analysis undertaken as part of this research, at the district and local municipality level, respectively. Each of the maps has the primary and secondary drainage basins indicated. Table 6.1 and 6.2 show the calculated impact potential scores determined at the district and local municipality level, respectively.

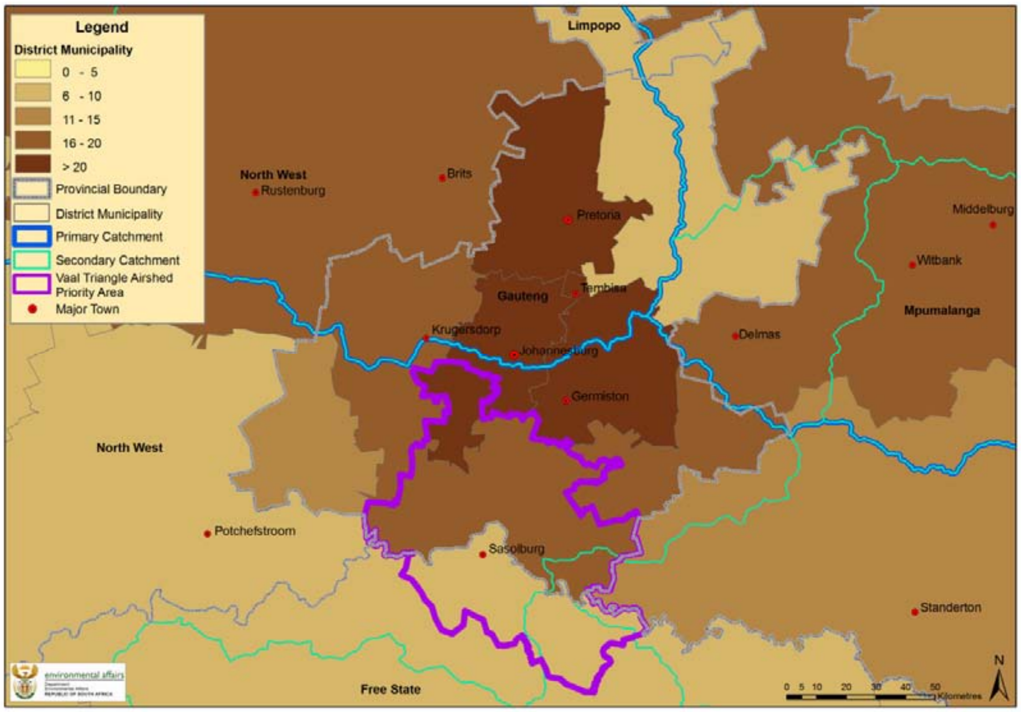

Figure 6.2 **VTAPA shown in relation to the estimated air pollution impact potential rating at the district municipality level**

Table 6.1 **Air pollution impact potential scores for the District Municipalities in and around the VTAPA**

Province	District / Metropolitan Municipality	Impact Score
Free State	Fezile Dabi District Municipality	8
Gauteng	Sedibeng District Municipality	16
Gauteng	City of Johannesburg Metropolitan Municipality	25
Gauteng	Ekurhuleni Metropolitan Municipality	26
Gauteng	West Rand District Municipality	17

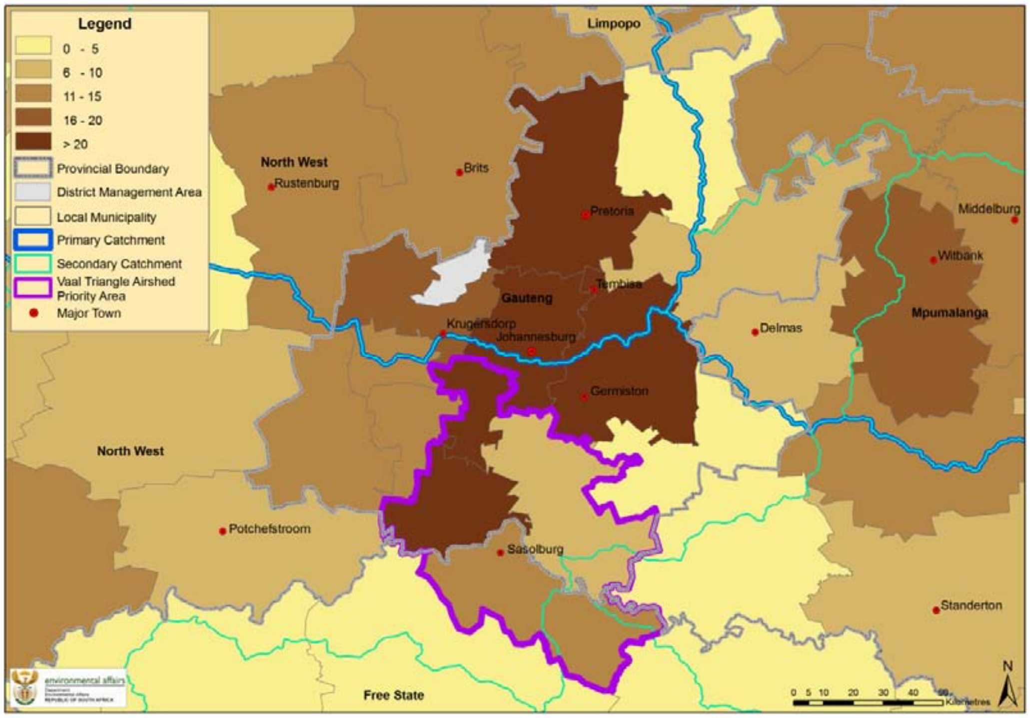

Figure 6.3 VTAPA shown in relation to the estimated air pollution impact potential rating at the local municipality level

Table 6.2 Air pollution impact potential scores for the Local Municipalities in and around the VTAPA

Province	District / Metropolitan Municipality	Local Municipality	Impact Score
Free State	Fezile Dabi	Metsimaholo	12
Gauteng	Sedibeng	Midvaal	7
Gauteng	Sedibeng	Lesedi	5
Gauteng	Sedibeng	Emfuleni	22
Gauteng	West Rand	Westonaria	15
Gauteng	West Rand	Randfontein	14
Gauteng	West Rand	Merafong City	13

All areas comprising the existing VTAPA have relatively high to medium air pollution impact potential, justifying their incorporation into the area. However an analysis of the topographical parameter indicates that the priority area should also include adjacent areas, namely the local municipalities of Westonaria, Randfontein and Merafong City in the West Rand District Municipality to the west, the local municipality of Lesedi in the Sedibeng District Municipality to the east and the Ekurhuleni Metropolitan Municipality to the north. Figure 6.4 shows the proposed revised delineation of the VTAPA. The inclusion of the Ekurhuleni Metropolitan

Municipality and the balance of the Sedibeng district municipality (Lesedi Local Municipality) are deemed controversial as these areas form part of the current Highveld Priority Area (HPA). The Lesedi Local Municipality has a low air pollution impact potential (5), but this area is considered significant since there is significant air pollution transport over this area from both the Ekurhuleni Metro and the Vaal Triangle due to prevailing winds. This recommendation is further strengthened by the results of the baseline modelling assessment undertaken for the VTAPA (DEAT, 2007b). Figures 6.5 and 6.6 shows the maximum modelled 24-hour PM_{10} and SO_2 concentrations within the VTAPA and surrounding areas. The location of the boundary of the primary catchment further strengthens the argument for the inclusion of the Ekurhuleni Metro into the VTAPA. It must be acknowledged at this stage that there will be significant inter-basin transfer of air pollution between the VTAPA and the HPA. Recommendations are made in Section 6.2.2 for the removal of Ekurhuleni and Lesedi from the current HPA.

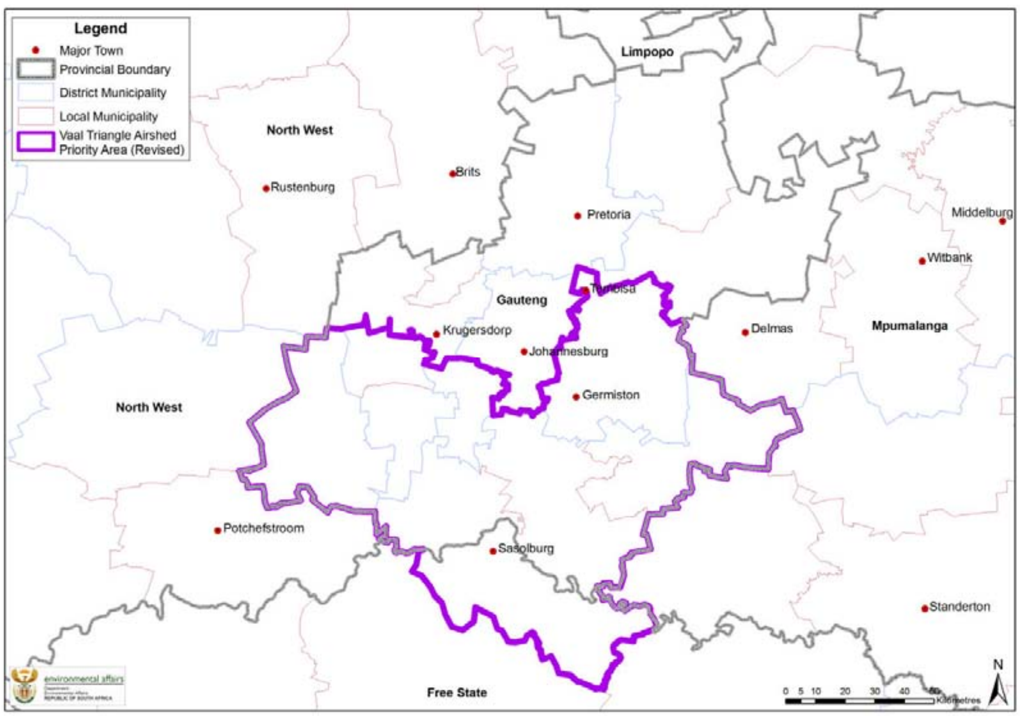

Figure 6.4 Proposed revised delineation of the VTAPA

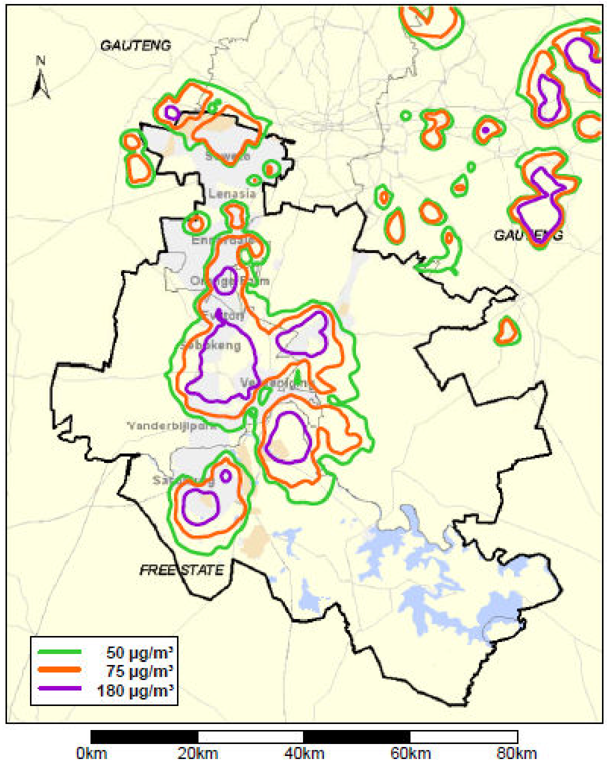

Figure 6.5 Maximum modelled 24-hour PM_{10} concentrations in the VTAPA (DEAT, 2007b)

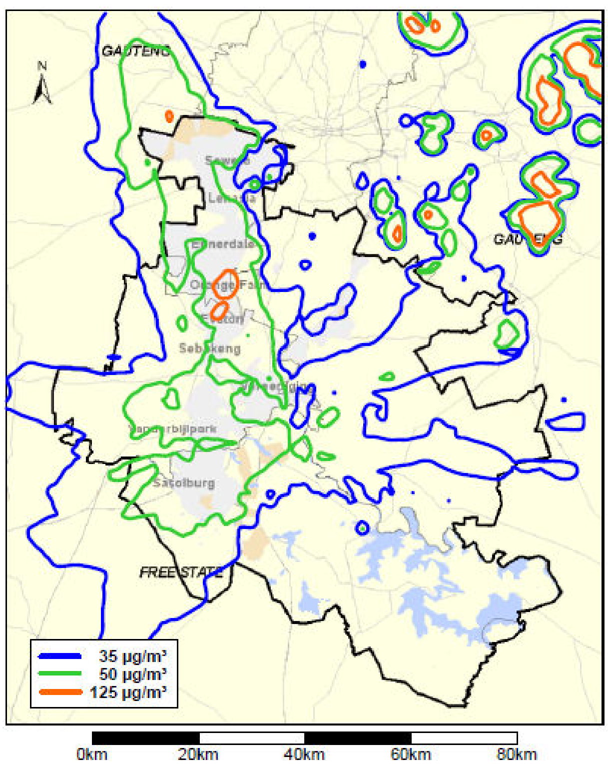

Figure 6.6 Maximum modelled 24-hour SO_2 concentrations in the VTAPA (DEAT, 2007b)

6.2.2 Highveld Priority Area

Figure 6.7 shows the extent of the Highveld Priority Area (HPA) declared on 23 November 2007. The area covers portions of the Gauteng and Mpumalanga provinces. District or metropolitan municipalities include Ekurhuleni, Sedibeng, Nkangala and Gert Sibande, while local municipalities include Lesedi, Delmas, Emalahleni, Steve Tshwete, Msukaligwa, Pixley ka Seme, Lekwa, Govan Mbeki and Dipaleseng.

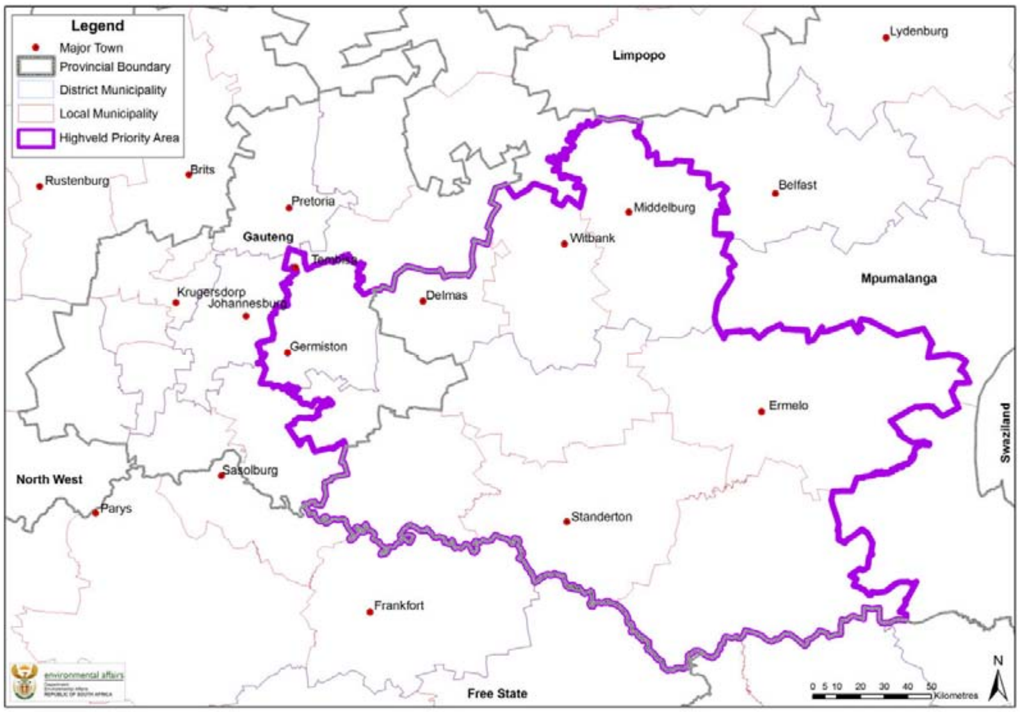

Figure 6.7 Extent of the Highveld Priority Area

Figures 6.8 and 6.9 shows the results of analysis undertaken as part of this research, at the district and local municipality level, respectively. Table 6.3 and 6.4 show the calculated impact potential scores determined at the district and local municipality level, respectively.

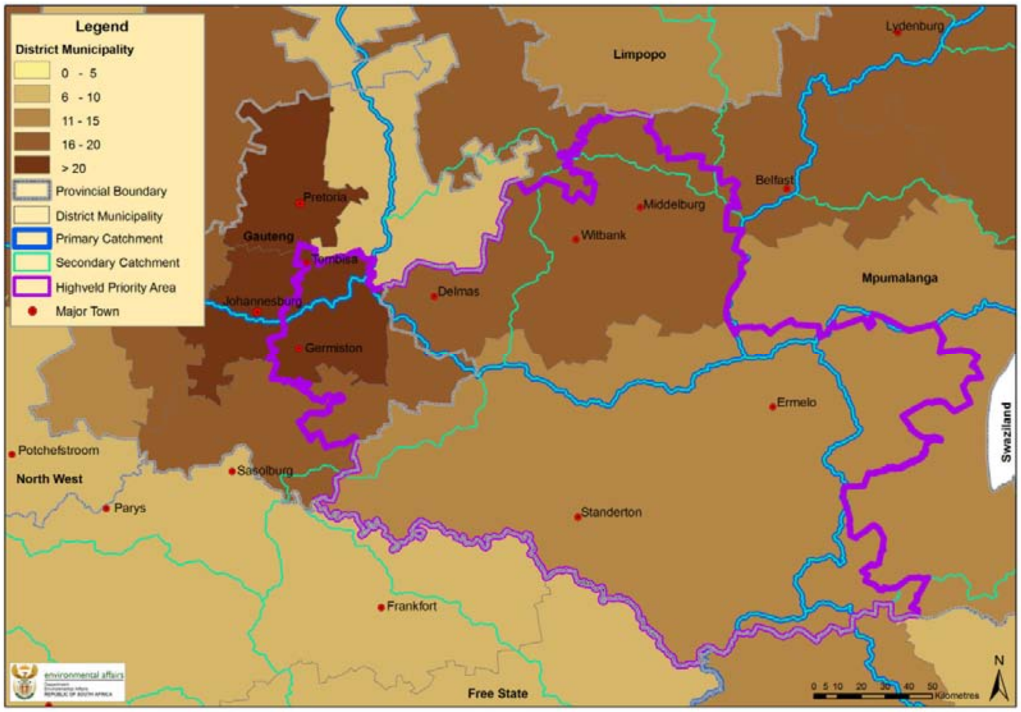

Figure 6.8 HPA shown in relation to the estimated air pollution impact potential rating at the district municipality level

Table 6.3 Air pollution impact potential scores for the District Municipalities in and around the HPA

Province	District / Metropolitan Municipality	Impact Score
Mpumalanga	Nkangala District Municipality	17
Mpumalanga	Gert Sibande District Municipality	13
Gauteng	Sedibeng District Municipality	16
Gauteng	City of Johannesburg Metropolitan Municipality	25
Gauteng	Ekurhuleni Metropolitan Municipality	26
Gauteng	Metsweding District Municipality	8
Limpopo	Greater Sekhukhune District Municipality	12

Significant revisions to the boundary of the HPA are recommended based on the results presented in Figures 6.8 and 6.9. It appears that the current delineation includes areas in the south with relatively low air pollution impact potential and excludes areas in the north that have relatively higher air pollution impact potential. The topographical analysis also confirms this recommendation. Figure 6.10 shows the proposed revised delineation of the Highveld Priority Area. This revised delineation sees the exclusion of the Ekurhuleni Metropolitan Municipality and the Lesedi Local Municipality (Sedibeng District Municipality), which is now recommended for inclusion in the VTAPA. All the local municipalities in the Gert Sibande District Municipality are excluded, with the exception of the Govan Mbeki Local Municipality.

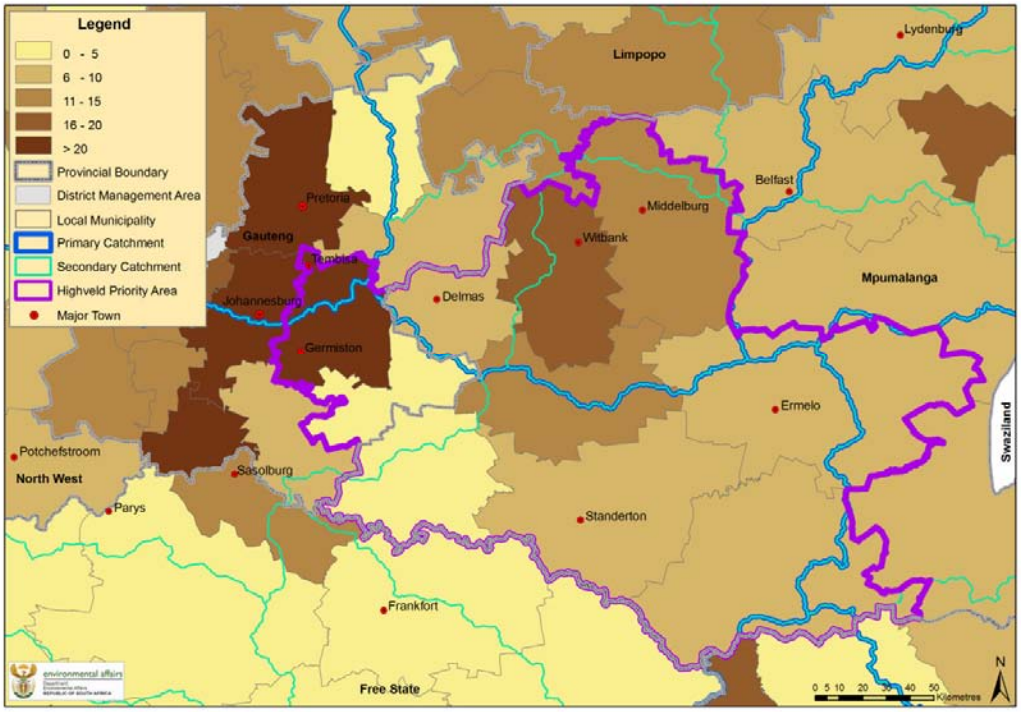

Figure 6.9 **HPA shown in relation to the estimated air pollution impact potential rating at the local municipality level**

Table 6.4 **Air pollution impact potential scores for the Local Municipalities in and around the HPA**

Province	District / Metropolitan Municipality	Local Municipality	Impact Score
Gauteng	Sedibeng	Lesedi	5
Gauteng	Metsweding	Kungwini	9
Mpumalanga	Nkangala	Delmas	10
Mpumalanga	Nkangala	Emalahleni	17
Mpumalanga	Nkangala	Steve Tshwete	11
Mpumalanga	Nkangala	Thembisile	11
Mpumalanga	Nkangala	Dr JS Moroka	12
Mpumalanga	Gert Sibande	Msukaligwa	8
Mpumalanga	Gert Sibande	Pixley ka Seme	6
Mpumalanga	Gert Sibande	Lekwa	6
Mpumalanga	Gert Sibande	Govan Mbeki	14
Mpumalanga	Gert Sibande	Dipaleseng	5
Limpopo	Greater Sekhukhune	Elias Motsoaledi	12

The Msukaligwa Local Municipality in the Nkangala District Municipality is also excluded. Additional areas to the north are recommended for inclusion in the HPA, these include the Kungwini Local Municipality in the Metsweding District Municipality, Thembisile Local

Municipality and Dr J.S. Moroka Local Municipality in Nkangala District Municipality and the Elias Motsoaledi Local Municipality in the Greater Sekhukhune District Municipality in Limpopo.

The recommendation for the revision of the boundary of the HPA is further strengthened by the preliminary modelling results of the baseline assessment for the HPA (DEA, 2010). Figure 6.11 shows the modelled results indicating the frequency of exceedence of ambient air quality standards only for industrial emissions in the HPA. The lack of exceedences in the southern and eastern areas confirms the findings of this research. The high numbers of exceedences modelled in the Ekurhuleni area confirms the results presented in Figures 6.5 and 6.6. It is the topographical influence of the primary and secondary catchment boundaries that lead to the recommendation for the inclusion of this area and the Lesedi Local Municipality area into the VTAPA. It must be noted that extensive inter-basin transfer between the VTAPA and the HPA will be expected to occur and that the two areas are merely separated for administrative and management purposes. It must be noted that the two air quality management plans for the national priority areas are managed by the national Department of Environmental Affairs under the auspices of the National Air Quality Officer, thus ensuring a co-ordinated approach to air quality management.

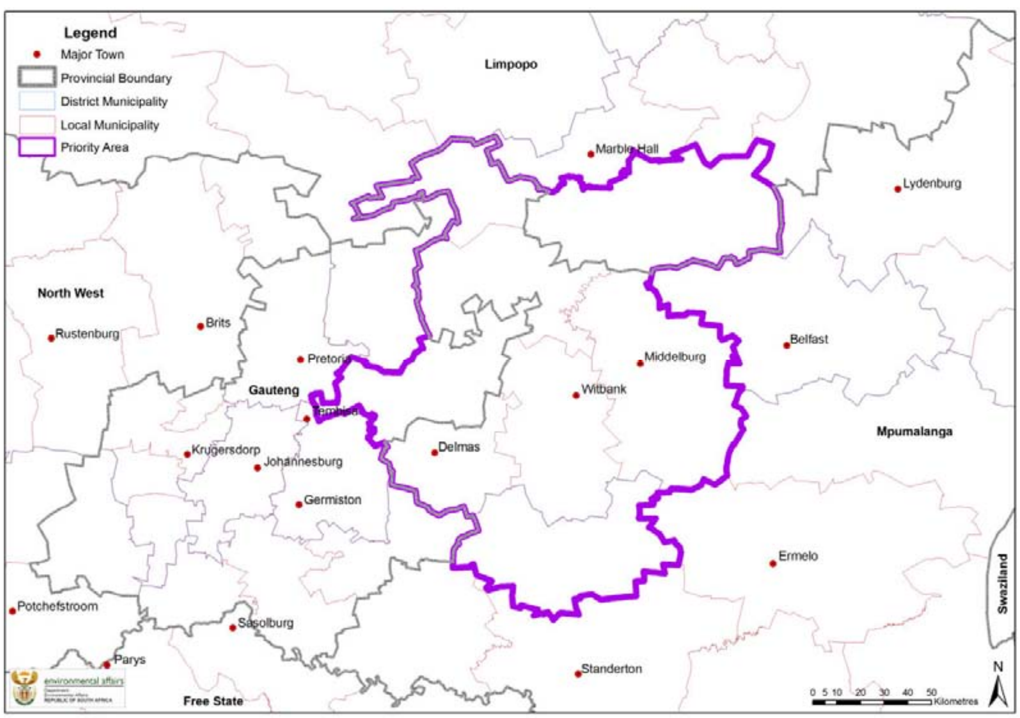

Figure 6.10 Proposed revised delineation of the HPA

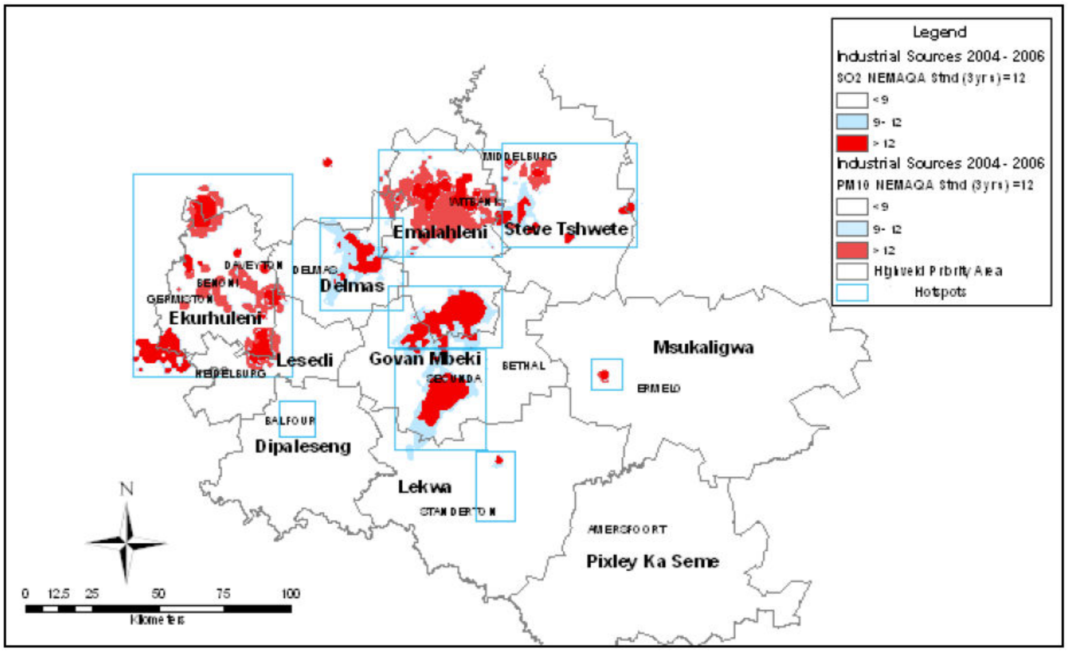

Figure 6.11 Modelled exceedences of SO_2 and PM_{10} in the HPA (DEA, 2010)

6.2.3 Proposed Magaliesberg Priority Area

Figure 6.12 shows the extent of the proposed Magaliesberg Priority Area (MPA). The area covers portions of the Gauteng and North-West Province. Since the proposed priority area crosses a provincial boundary the area is considered a national priority area. Metropolitan municipalities included in the proposed priority area include the City of Tshwane and the City of Johannesburg. District municipalities included in the proposed priority area include West Rand and Bojanala, while local municipalities include Mogale City, Madibeng and Rustenburg. The complex topography in this area, namely the Magaliesberg Mountains, strongly influences dispersion and drainage patterns and forms a natural barrier within the proposed area. The area is characterised by a combination of high density urban residential areas together with rural industrial and mining activities. There is ambient air quality monitoring taking place in the City of Tshwane and in Rustenburg but little is known or understood regarding the transfer of pollution between these two areas. Tables 6.5 and 6.6 show the calculated impact potential scores determined at the district and local municipality level, respectively.

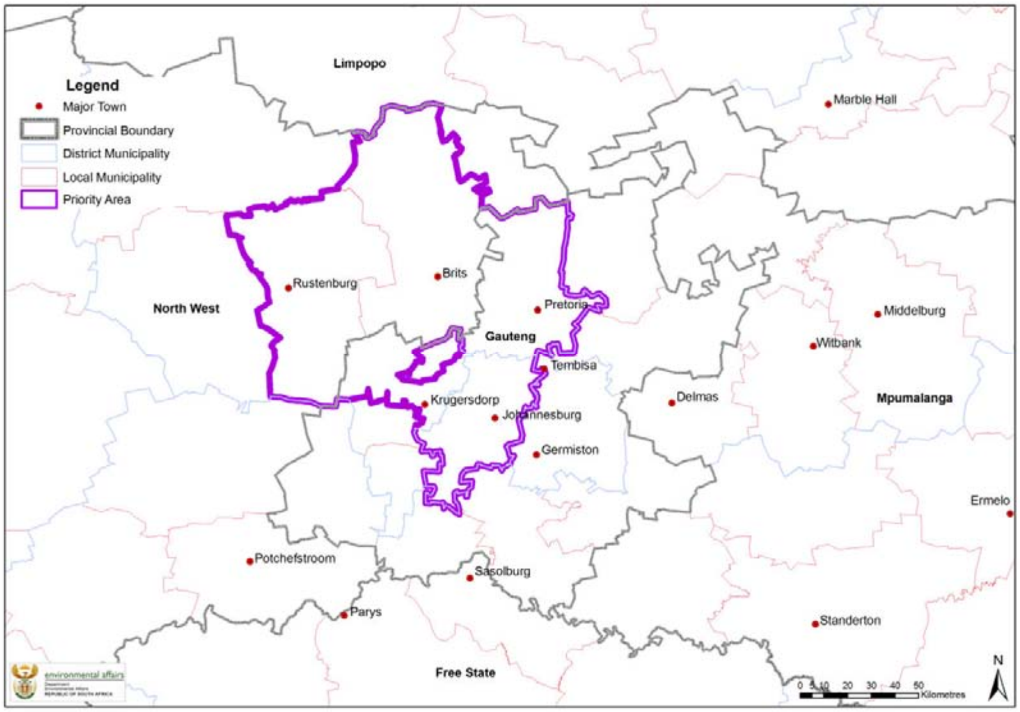

Figure 6.12 Extent of the proposed Magaliesberg Priority Area

Table 6.5 Air pollution impact potential scores for the District Municipalities in the proposed MPA

Province	District / Metropolitan Municipality	Impact Score
Gauteng	City of Tshwane Metropolitan Municipality	24
Gauteng	City of Johannesburg Metropolitan Municipality	25
Gauteng	West Rand District Municipality	17
North West	Bojanala District Municipality	16

Table 6.6 Air pollution impact potential scores for the Local Municipalities in the proposed MPA

Province	District / Metropolitan Municipality	Local Municipality	Impact Score
Gauteng	West Rand	Mogale City	17
Gauteng	City of Johannesburg	n/a	25
Gauteng	City of Tshwane	n/a	24
North West	Bojanala	Madibeng	12
North West	Bojanala	Rustenburg	14

6.2.4 Proposed Waterberg Priority Area

Figure 6.13 shows the extent of the proposed Waterberg Priority Area (WPA). The area incorporates all six local municipalities within the Waterberg District Municipality. Figures 5.13 and 5.14 do not identify this area as having high air pollution impact potential, however the proposed priority area is identified based on the extensive development proposals currently under consideration in the area. These include three new coal fired power stations, one of which is currently under construction, the development of a new coal to liquid (CTL) facility and other coal based industries. Current and future emissions from this area have the potential to impact on Botswana located to the north. This is in addition to the developments currently planned on the Botswana side of the border, which include two new coal-fired power stations and a potential CTL facility. Since this area has the future potential to impact on areas outside of the borders of the country it is considered as a national priority area, even though it does not cross a provincial boundary. The DEA is currently considering declaring this area as the third national priority area, as a proactive management measure. In the past the previous national priority areas have been declared on a reactive basis. Table 6.7 show the calculated impact potential scores determined at the local municipality level. This information confirms that the area is not currently impacted by poor air quality.

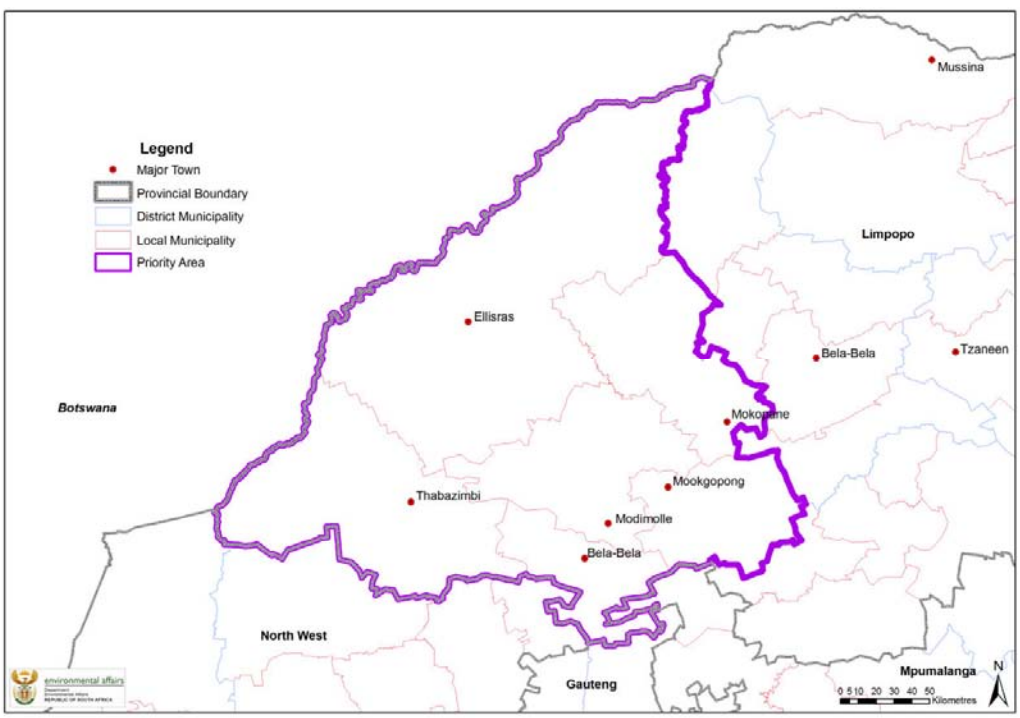

Figure 6.13 Extent of the proposed Waterberg Priority Area

Table 6.7 Air pollution impact potential scores for the Local Municipalities in the proposed WPA

Province	District / Metropolitan Municipality	Local Municipality	Impact Score
Limpopo	Waterberg	Thabazimbi	5
Limpopo	Waterberg	Modimolle	5
Limpopo	Waterberg	Mogalakwena	10
Limpopo	Waterberg	Bela Bela	6
Limpopo	Waterberg	Mookgopong	4
Limpopo	Waterberg	Lephalale	5

6.3 Provincial Implications

6.3.1 Eastern Cape

Table 6.8 shows the calculated impact potential scores determined at the district municipality level in the Eastern Cape. The Nelson Mandela Bay Metropolitan Municipality (NMBMM) has the highest industrial activity, highest population density and the second highest concentration of mining activities in the province. The province has an extremely poor coverage of ambient air quality monitors, as highlighted in Figures 1.2 – 1.4. No adjacent district / metros in the Eastern Cape can be considered as potential provincial priority areas.

Table 6.8 Air pollution impact potential scores for the District / Metropolitan Municipalities in the Eastern Cape

Province	District / Metropolitan Municipality	Impact Score
Eastern Cape	Alfred Nzo District Municipality	9
Eastern Cape	Ukhahlamba District Municipality	5
Eastern Cape	Chris Hani District Municipality	8
Eastern Cape	O.R. Tambo District Municipality	11
Eastern Cape	Cacadu District Municipality	5
Eastern Cape	Amathole District Municipality	13
Eastern Cape	Nelson Mandela Bay Metropolitan Municipality	23

6.3.2 Free State

The Free State is characterised by low population densities due to the predominant agricultural activities in the province. The Fezile Dabi District Municipality has the highest industrial activity, however the bulk of this activity is concentrated in the north in the Metsimaholo Local

Municipality (Sasolburg). This district forms part of the Vaal Triangle Airshed Priority Area. The highest concentration of mining activity is in the Lejweleputswa District Municipality, which contains a high concentration of gold mines. The road density in the Free State is generally low with only one major urban centre (Bloemfontein) in the province. Table 6.9 shows the calculated impact potential scores determined at the district municipality level in the Free State. No other adjacent districts in the Free State can be considered as potential provincial priority areas.

Table 6.9 Air pollution impact potential scores for the District Municipalities in the Free State

Province	District / Metropolitan Municipality	Impact Score
Free State	Xhariep District Municipality	4
Free State	Thabo Mofutsanyane District Municipality	7
Free State	Lejweleputswa District Municipality	7
Free State	Motheo District Municipality	8
Free State	Fezile Dabi District Municipality	8

6.3.3 Gauteng

The Gauteng province is the economic hub of the country with the highest industrial, population and road densities. The central regions of the province are highly urbanised, with lower population densities on the periphery. The Ekurhuleni Metropolitan Municipality has the highest industrial density of any district or metro in the country and forms part of the HPA. The Sedibeng District Municipality falls both within the VTAPA and HPA, while the southern parts of the City of Johannesburg Metropolitan Municipality fall within the VTAPA. Due to the fact that the districts and metros with significant air pollution impact potential are already incorporated in national priority areas there is limited scope for the declaration of provincial priority areas in Gauteng. Table 6.10 provides a summary of the calculated impact potential scores determined at the district / metropolitan municipality level in Gauteng. There is an industrial, commercial and residential corridor developing between The City of Johannesburg Metropolitan Municipality and the City of Tshwane Metropolitan Municipality. The combination of population density, industrial activity and road density identifies this as a future potential provincial priority area. Figure 6.14 shows the extent of the proposed Johannesburg / Tshwane Provincial Priority Area. The area incorporates the northern suburbs of the City of Johannesburg, Midrand and the City of Tshwane.

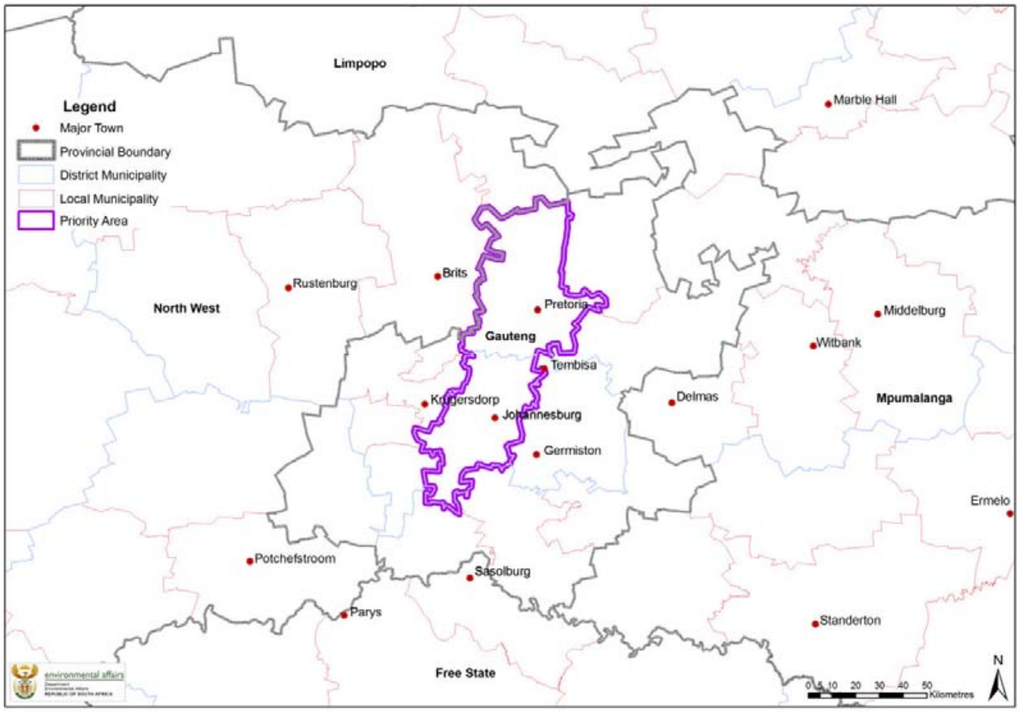

Figure 6.14 Extent of the proposed Johannesburg / Tshwane Provincial Priority Area

Table 6.10 Air pollution impact potential scores for the District / Metropolitan municipalities in Gauteng

Province	District / Metropolitan Municipality	Impact Score
Gauteng	Metsweding District Municipality	8
Gauteng	West Rand District Municipality	17
Gauteng	Sedibeng District Municipality	16
Gauteng	City of Johannesburg Metropolitan Municipality	25
Gauteng	City of Tshwane Metropolitan Municipality	24
Gauteng	Ekurhuleni Metropolitan Municipality	26

6.3.4 KwaZulu-Natal

The Ethekwini Metropolitan Municipality has the highest population density, industrial activity and road density in the province. The balance of the province is characterised as predominantly rural with urban pockets. The industrial hubs of Newcastle (Amajuba District Municipality), Richards Bay (Uthungulu District Municipality) and Pietermaritzburg (Umgungundlovu District Municipality) are clearly visible but this can be attributed to the dominance of the individual local municipalities within the district, rather than a district wide effect. The districts surrounding the Ethekwini Metro provide the potential for the declaration of a provincial priority area.

To the north, the Ethekwini Metro is bordered by the iLembe District Municipality. The development of new international airport, and the associated industrial hub, on the border between these two areas may justify the declaration of the provincial priority area in the future. Figure 6.15 shows the extent of the proposed iLembe / Ethekwini Provincial Priority Area. The area includes the Ethekwini Metropolitan Municipality and the local municipalities of KwaDukuza and eDondakusuka in the iLembe District Municipality. The rapid residential and commercial expansion of the lower North Coast (Ballito, Umhlali etc.) provides further justification for the declaration of this area. The recent opening of the King Shaka International Airport in this area adds additional to the air pollution impact potential since this has been co-developed with a trade port. The prevailing synoptic winds in the area are north-easterly and south-westerly, which would transport pollution south from the iLembe District Municipality or north from the Ethekwini Metro (Preston-Whyte, 1980). It is recommended that a programme of ambient air quality monitoring is commenced in the area. Table 6.11 summarises the calculated impact potential scores determined at the district / metropolitan and local municipality level.

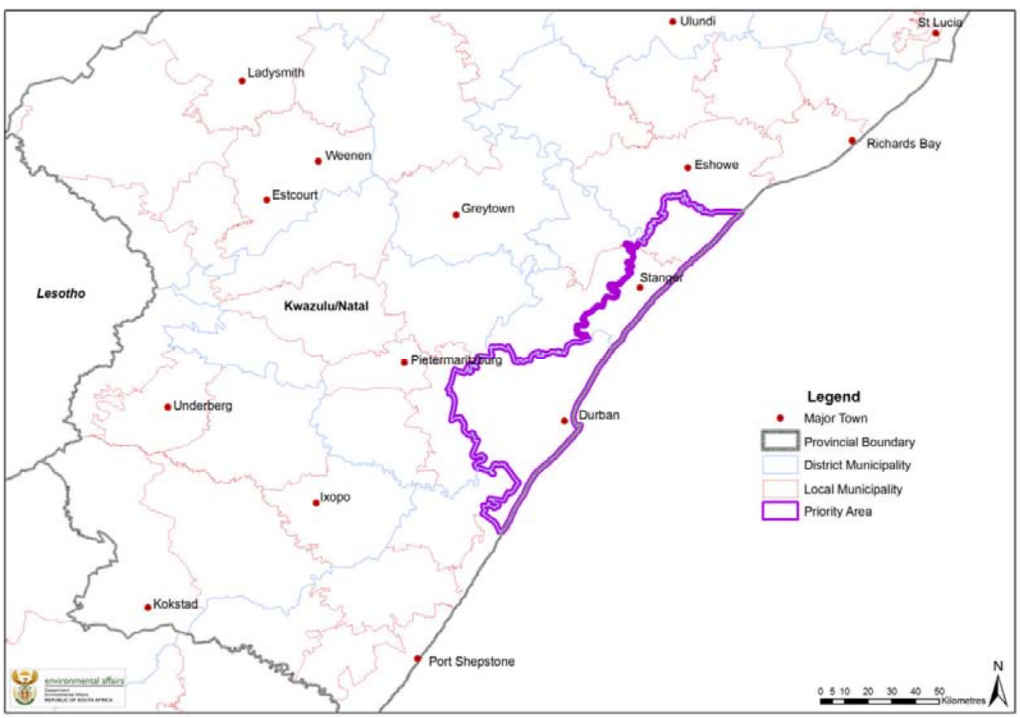

Figure 6.15 Extent of the proposed iLembe / Ethekwini provincial priority area

Table 6.11 Air pollution impact potential scores for the municipalities in the proposed iLembe / Ethekwini provincial priority area

Province	District / Metropolitan Municipality	Local Municipality	Impact Score
KwaZulu Natal	Ethekwini	n/a	26
KwaZulu Natal	iLembe	KwaDukuza	15
KwaZulu Natal	iLembe	eDondakusuka	16

To the west, the Ethekwini Metro is bordered by the uMgungundlovu District Municipality. The rapid residential and commercial expansion of the Outer West regions (Hillcrest, Bothas Hill) combined with the industrial development of the Cato Ridge area may justify the future declaration of this area as a provincial priority area. There is a distinct topographical barrier (Key Ridge) that separates the two areas, but katabatic drainage down river valleys transport air pollution from the interior to the coast. Figure 6.16 shows the extent of the proposed uMgungundlovu / Ethekwini provincial priority area. The area includes the Ethekwini Metropolitan Municipality and the local municipalities of Msunduzi and Mkhambathini in the uMgungundlovu District Municipality. Table 6.12 summarises the calculated impact potential scores determined at the district / metropolitan and local municipality level.

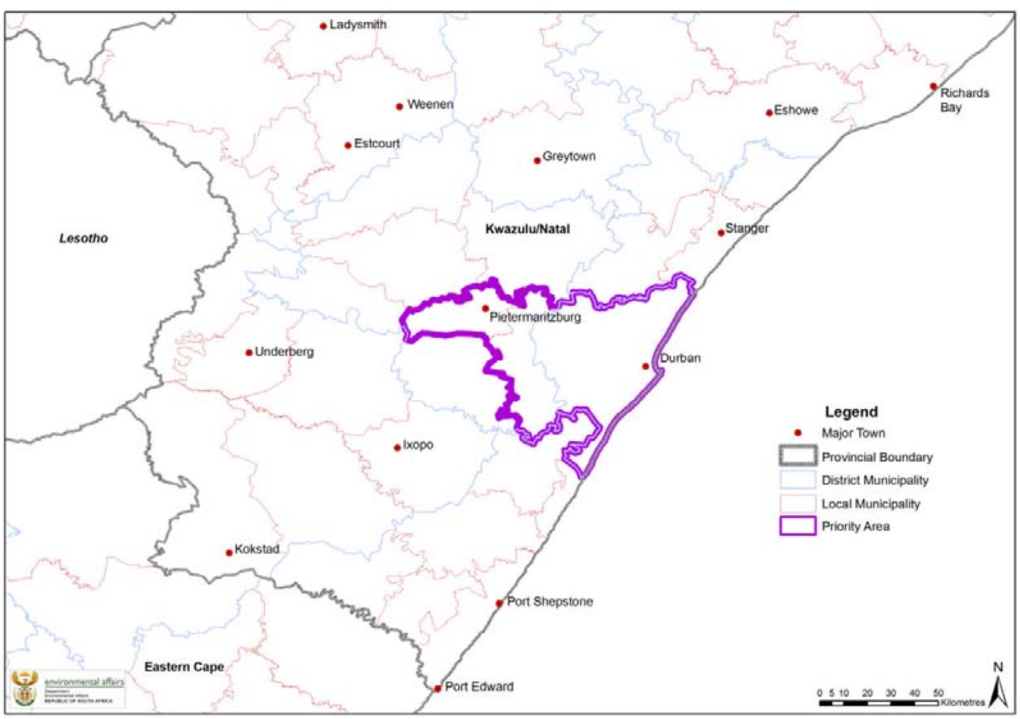

Figure 6.16 Extent of the proposed uMgungundlovu / Ethekwini provincial priority area

Table 6.12 Air pollution impact potential scores for the municipalities in the proposed uMgungundlovu / Ethekwini provincial priority area

Province	District / Metropolitan Municipality	Local Municipality	Impact Score
KwaZulu Natal	Ethekwini	n/a	26
KwaZulu Natal	uMgungundlovu	Msunduzi	21
KwaZulu Natal	uMgungundlovu	Mkhambathini	12

To the south, the Ethekwini Metro is bordered by the Ugu District Municipality. The Ugu District Municipality is characterised by ribbon development along the coastal areas, with a rural interior, dominated by agriculture. While the Ugu District Municipality has a relatively high pollution impact potential, due to industrial emissions and mining density, these activities are concentrated along the coastal regions. The prevailing synoptic winds in the area are north-easterly and south-westerly, which would transport pollution south from the Ethekwini Metro or north from the Ugu District (Preston-Whyte, 1980). There is long term, high quality ambient air quality monitoring information in the southern parts of the Ethekwini Metro and in the border areas (Umkomaas). Further analysis of this ambient data may justify the declaration of a provincial priority area. Figure 6.17 shows the extent of the proposed Ugu / Ethekwini provincial priority area.

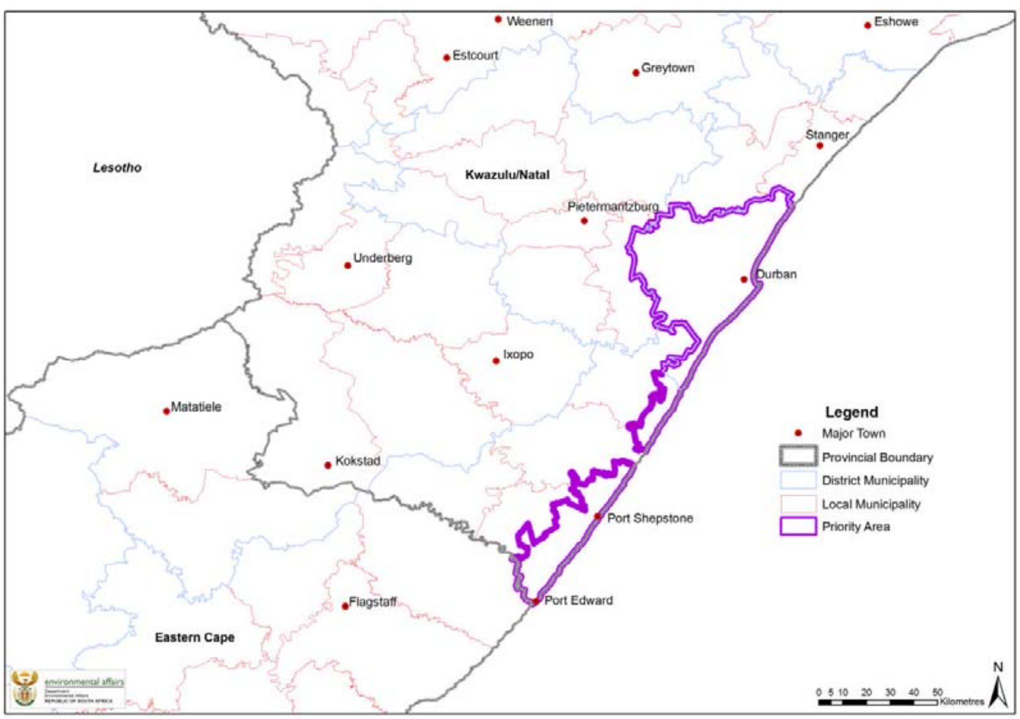

Figure 6.17 Extent of the proposed Ugu / Ethekwini provincial priority area

The area includes the Ethekwini Metropolitan Municipality and the local municipalities of uMdoni and Hibiscus Coast in the Ugu District Municipality. Table 6.13 summarises the calculated impact potential scores determined at the district / metropolitan and local municipality level.

Table 6.13 Air pollution impact potential scores for the municipalities in the proposed Ugu / Ethekwini provincial priority area

Province	District / Metropolitan Municipality	Local Municipality	Impact Score
KwaZulu Natal	Ethekwini	n/a	26
KwaZulu Natal	Ugu	uMdoni	18
KwaZulu Natal	Ugu	Hibiscus Coast	18

6.3.5 Limpopo

The Mopani District Municipality has the highest population density, together with the highest industrial impact and road density in the province. The province is predominantly rural with pockets of urban development. Mining activities in this province are concentrated along the eastern limb of the Bushveld Igneous Complex. Table 6.14 provides a summary of the calculated impact potential scores determined at the district / metropolitan municipality level in Limpopo. No adjacent districts in Limpopo can be considered as potential provincial priority areas.

Table 6.14 Air pollution impact potential scores for the district municipalities in Limpopo

Province	District / Metropolitan Municipality	Impact Score
Limpopo	Capricorn District Municipality	11
Limpopo	Greater Sekhukhune District Municipality	12
Limpopo	Vhembe District Municipality	11
Limpopo	Waterberg District Municipality	6
Limpopo	Mopani District Municipality	13

6.3.6 Mpumalanga

All three districts within the Mpumalanga province are similar with regards to their industrial impact, mining density and road density. The Gert Sibande District Municipality has a lower population density. Parts of the Nkangala and Gert Sibande District Municipalities are included in the HPA. The Ehlanzeni District Municipality is disjunct from the other districts due to topography. Due to the inclusion of a large portion of this province in the HPA no adjacent districts in Mpumalanga can be considered as potential provincial priority areas. Table 6.15 provides a summary of the calculated impact potential scores determined at the district / metropolitan municipality level in Mpumalanga.

Table 6.15 Air pollution impact potential scores for the District Municipalities in Mpumalanga

Province	District / Metropolitan Municipality	Impact Score
Mpumalanga	Ehlanzeni District Municipality	16
Mpumalanga	Gert Sibande District Municipality	13
Mpumalanga	Nkangala District Municipality	17

6.3.7 North West

The Bojanala District Municipality has the highest industrial impact and mining density in the province. This district borders on the West Rand District Municipality and the City of Tshwane Metro in Gauteng. The Magaliesberg provides a topographical barrier between the areas, otherwise this may have been considered a potential national priority area. Mining activities in this province are concentrated along the western limb of the Bushveld Igneous Complex. The province can be characterised as rural with urban pockets. The towns of Klersdorp (Dr Kenneth Kauanda District Municipality), Potchefstroom (Dr Kenneth Kauanda District Municipality), Rustenburg (Bojanala District Municipality) and Brits (Bojanala District Municipality) are the major industrial hubs in the province. Table 6.16 provides a summary of the calculated impact potential scores determined at the district / metropolitan municipality level in the North West. Due to the isolated nature of the urban centres no adjacent districts in the North West can be considered as potential provincial priority areas.

Table 6.16 Air pollution impact potential scores for the District Municipalities in the North West

Province	District / Metropolitan Municipality	Impact Score
North West	Ngaka Modiri Molema District Municipality	8
North West	Dr Ruth Segomotsi Mompati District Municipality	5
North West	Dr Kenneth Kaunda District Municipality	9
North West	Bojanala District Municipality	16

6.3.8 Northern Cape

The Northern Cape has the lowest population density in the country. The Siyanda and France Baard District Municipalities are the only areas with any significant industrial development. The road density in the Frances Baard District Municipality is the highest in the province. Mining activity in the province is relatively high due to the presence of diamonds in Kimberley and along the Orange River. Table 6.17 provides a summary of the calculated impact potential scores determined at the district / metropolitan municipality level in the Northern Cape. No adjacent districts in the Northern Cape can be considered as potential provincial priority areas.

Table 6.17 Air pollution impact potential scores for the District Municipalities in the Northern Cape

Province	District / Metropolitan Municipality	Impact Score
Northern Cape	Kgalagadi District Municipality	4
Northern Cape	Pixley ka Seme District Municipality	4
Northern Cape	Namaqwa District Municipality	4
Northern Cape	Siyanda District Municipality	4
Northern Cape	Frances Baard District Municipality	8

6.3.9 Western Cape

The City of Cape Town Metro has the highest population density, industrial impact and road density in the province. The coastal fringes of the province are considered to be developed with a predominantly rural interior. The industrial hub of Saldanha Bay heavily weights the West Coast District Municipality rating, with the same applying to the Mossel Bay and George in the Eden District Municipality. The districts surrounding the City of Cape Town Metro provide the potential for the declaration of a potential provincial priority area. The Overberg District Municipality to the east is not considered a potential priority area due to the limited air pollution potential of this district. However, the western regions of the Cape Winelands (Stellenbosch and Drakenstein Local Municipalities) and the southern region of the West Coast (Swartland Local Municipality) border directly onto the City of Cape Town Metro. The topography of the area (Cape Fold Mountains) may limit the cross-boundary impact but drainage through inter-connecting valleys may impact on adjacent areas. Table 6.18 summarises the calculated impact potential scores determined at the district / metropolitan and local municipality level. Figure 6.18 shows the extent of the proposed Cape Winelands / West Coast / Cape Town provincial priority area.

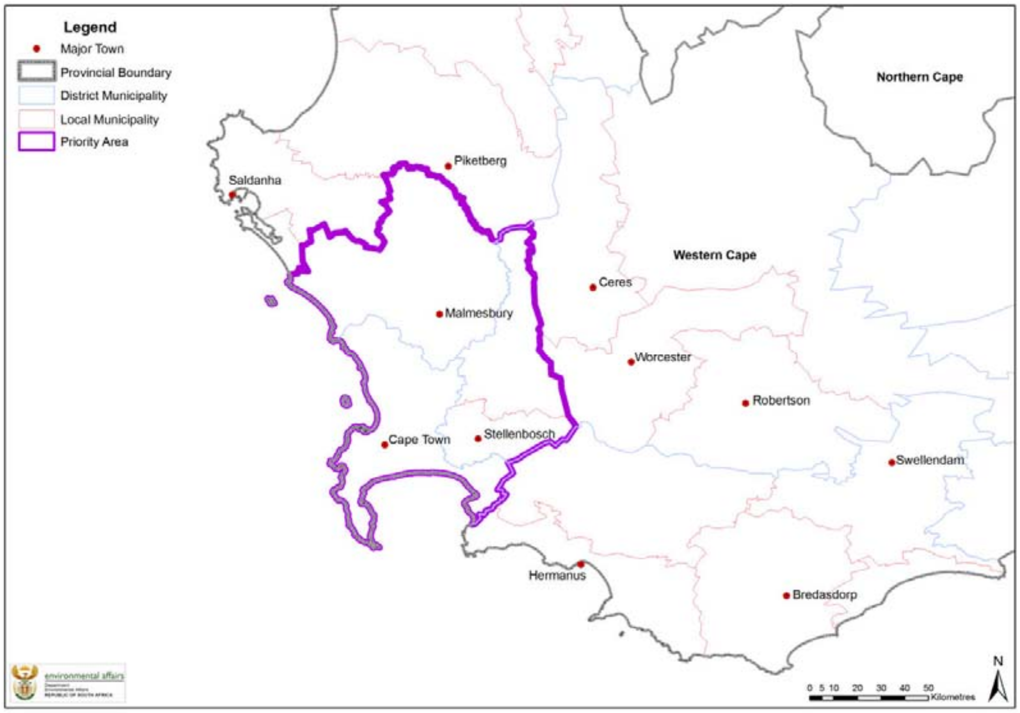

Figure 6.18 Extent of the proposed Cape Winelands / West Coast / Cape Town provincial priority area

Table 6.18 Air pollution impact potential scores for the municipalities in the proposed Cape Winelands / West Coast / City of Cape Town provincial priority area

Province	District / Metropolitan Municipality	Local Municipality	Impact Score
Western Cape	City of Cape Town	n/a	22
Western Cape	Cape Winelands	Stellenbosch	11
Western Cape	Cape Winelands	Drakenstein	11
Western Cape	West Coast	Swartland	8

This area includes the City of Cape Town, the local municipalities of Stellenbosch and Drakenstein in the Cape Winelands District Municipality and the local municipality of Swartland in the West Coast District Municipality. While extensive ambient air quality monitoring is taking place in the City of Cape Town Metro, limited ambient monitoring is taking place in the Cape Winelands and West Coast District Municipalities. It is recommended that a programme of ambient air quality monitoring takes place in the inter-connecting areas.

6.4 Local Government Implications

Table 24 of the National Framework provided a subjective assessment of the air quality in all metropolitan and district municipalities of South Africa. The municipalities were rated as either; “Acceptable” – generally good air quality; “Potentially Poor” – air quality may be poor at times or deteriorating or “Poor” – ambient air quality standards regularly exceeded. This assessment was based on limited ambient air quality monitoring data, where available, results of dispersion modelling studies, strategic environmental impact assessments and other proxy information. This original table listed all six metropolitan municipalities and 22 district municipalities, however the Free State and portions of the Northern Cape were inadvertently excluded from the table. Table 6.19 provides a corrected summary of six metros and 28 district municipalities. As part of the revision to the National Framework this table has been expanded to identify the specific local municipalities within the districts with poor or potentially poor air quality. In total, 48 local municipalities were identified. Table 6.1 also includes a revised assessment of the air pollution potential of each of the local municipalities based on the results of this research. Areas with an air pollution impact potential rating of ≤ 15 were deemed to have acceptable air quality, a rating of 16 – 25 was deemed to be potentially poor, while a rating ≥ 26 was deemed to be poor.

The revised air quality rating assessment saw the reclassification of 32 of the local municipalities to lower ratings. Only one district municipality and one local municipality were reclassified to a higher rating, having previously not being included in the summary. This indicates that the preliminary assessment was conservative in nature. Based on the air pollution impact potential assessment rating derived from this research, all six of the metropolitan municipalities have poor air quality, 15 district municipalities and 21 local municipalities have either poor or potentially poor air quality.

Table 6.19 Revised Table 24 of the National Framework (after DEAT, 2007a)

Province	Metro / District Municipality	Local Municipality	Initial Air Quality Rating (Table 24)	Revised Air Quality Rating (This Research)
Eastern Cape	Nelson Mandela Bay Metro	n/a	Poor	Poor
	Amathole DM	Buffalo City	Potentially Poor	Potentially Poor
Free State	Motheo DM	Mangaung	Potentially Poor	Acceptable
	Lejweleputswa DM	Matjhabeng	Potentially Poor	Acceptable
	Fezile Dabi DM	Metsimaholo	Poor	Acceptable
Gauteng	City of Johannesburg Metro	n/a	Poor	Poor
	City of Tshwane Metro	n/a	Poor	Poor
	Ekurhuleni Metro	n/a	Poor	Poor
	West Rand DM	Randfontein	Potentially Poor	Potentially Poor
		Westonaria	Potentially Poor	Potentially Poor
		Mogale City	Poor	Potentially Poor
		Merafong City	Potentially Poor	Acceptable
	Sedibeng DM	Emfuleni	Poor	Poor
		Midvaal	Poor	Acceptable
		Lesedi	Poor	Acceptable
	Metsweding DM	Kungwini	Potentially Poor	Acceptable
		Nokeng tsa Taemane	Potentially Poor	Acceptable
KwaZulu-Natal	Ethekwini Metro	n/a	Poor	Poor
	uMgungundlovu DM	The Msunduzi	Potentially Poor	Potentially Poor
	Uthukela DM	Emnambithi-Ladysmith	Potentially Poor	Acceptable
		Umtshezi	Potentially Poor	Acceptable
	iLembe DM	eDondekusuka	Potentially Poor	Potentially Poor
		KwaDukuza	Potentially Poor	Potentially Poor
	Uthungulu DM	uMhlathuze	Poor	Potentially Poor
	Amajuba DM	Newcastle	Potentially Poor	Potentially Poor
	Ugu DM	Umdoni	Potentially Poor	Potentially Poor
		Hibiscus Coast	Potentially Poor	Potentially Poor

Limpopo	Mopani DM	Ba-Phalaborwa	Potentially Poor	Acceptable
	Capricorn DM	Polokwane	Potentially Poor	Potentially Poor
	Waterberg DM	Lephalale	Potentially Poor	Acceptable
	Greater Sekhukhune DM	Greater Tubatse	Potentially Poor	Acceptable
	Vhembe DM	Thulamela	Acceptable	Potentially Poor
Mpumalanga	Ehlanzeni DM	Thaba Chweu	Potentially Poor	Acceptable
		Mbombela	Potentially Poor	Potentially Poor
		Umjindi	Potentially Poor	Acceptable
	Gert Sibande DM	Msukaligwa	Poor	Acceptable
		Pixley Ka Seme	Poor	Acceptable
		Lekwa	Poor	Acceptable
		Dipaleseng	Poor	Acceptable
	Nkangala DM	Delmas	Poor	Acceptable
		Emalahleni	Poor	Potentially Poor
		Steve Tshwete	Poor	Potentially Poor
North-West	Bojanala Platinum DM	Madibeng	Potentially Poor	Potentially Poor
		Rustenburg	Poor	Potentially Poor
	Dr Kenneth Kaunda DM	City of Matlosana	Potentially Poor	Potentially Poor
Northern Cape	Kgalagadi DM	Gamgara	Potentially Poor	Acceptable
	Siyanda DM	//Khara Hais	Potentially Poor	Acceptable
	Frances Baard DM	Sol Plaatjie	Potentially Poor	Potentially Poor
Western Cape	City of Cape Town Metro	n/a	Poor	Poor
	West Coast DM	Saldanha Bay	Poor	Acceptable
	Cape Winelands DM	Drakenstein	Potentially Poor	Acceptable
		Stellenbosch	Potentially Poor	Acceptable
	Eden DM	Mossel Bay	Potentially Poor	Acceptable
		George	Potentially Poor	Acceptable

6.5 Summary of the Implications

The revision of the boundaries of the existing national priority areas is deemed controversial as the authorities in the VTAPA have developed an extensive air quality management plan that is currently under implementation. The HPA is currently undertaking their baseline assessment, including an extensive dispersion modelling study. The revision of the boundaries would require extensive rework of the baseline assessments and air quality management planning initiatives, with significant cost and time implications. Given the limited financial resources assigned to air quality management in South Africa, the revision of the boundaries of these existing national priority areas is not advisable at this time. In addition, this would merely delay the implementation of the necessary interventions to improve the air quality in those areas where ambient air quality standards are being exceeded. It is recommended that the revisions to the boundaries are considered during the formal five-yearly review phase of the priority area management plan.

As indicated in Section 6.1, to date no provincial priority areas have been declared. The provincial priority areas presented in the Chapter above are proposed for consideration by the provincial authorities. In many cases, additional ambient air quality monitoring and research will be required to justify the declaration of these areas as provincial priority areas. One area that warrants immediate consideration is the City of Johannesburg / City of Tshwane provincial priority area. Both areas have ambient air quality monitoring which confirms the findings of this research and the area contains over 10% of the total population of the country.

The district and local municipalities identified in Table 6.19 are those that should be prioritised in terms of the roll out of the national ambient air quality monitoring network. The DEA has a programme starting in 2010 for the expansion of the national ambient air quality monitoring network. The objective of this network is to provide credible scientific information to guide air quality management in the country. The municipalities identified in Table 6.19 should also be prioritised in terms of assistance for the development of their air quality management plans. This ensures that the limited financial and human resources assigned to air quality management are deployed in those areas with the greatest need.

CHAPTER SEVEN
CONCLUSIONS AND RECOMMENDATIONS

7.1 Introduction

Air quality management in South Africa has been in a transitional phase since the partial entry into effect of the AQA in September 2005. With full promulgation of the Act scheduled for 1 April 2010, the transition of the air quality management function from national to local government will be complete. Concerns have been raised regarding the capacity of local government to undertake this responsibility. The AQA sees the introduction of a number of new air quality management tools, one of which is priority area management. This air quality management tool has three strategic drivers. Firstly, it allows for the concentration of limited air quality management capacity when dealing with acknowledged air pollution problem areas. Secondly, it prescribes co-operative governance that may become problematic in areas where cross boundary air pollution problems occur and finally, it allows for the application of holistic air quality management methodologies, namely airshed air quality management. Unfortunately the legislation, which is framework in nature, provides little guidance on the identification of the boundaries of these areas.

The goal of this research was to develop a methodology for the delineation of the boundary of an air quality management area in South Africa. The preliminary objective of the research was to identify the specific criteria that should be considered when developing the methodology. A review of the methodologies used internationally was undertaken, looking specifically at regions and countries with similar effects-based air quality legislation. The review concluded that the international practice regarding boundary determination was data intensive, relying heavily on the results of ambient air quality monitoring and the results of dispersion modelling based on comprehensive emissions inventories. Another commonality between the methodologies was the use of administrative boundaries as the borders of air quality management areas. South Africa has limited ambient air quality monitoring and there is no national emissions inventory for criteria pollutants. In the absence of this information an alternative approach was required. The next objective of the research was to identify or develop a proxy methodology for assessing the impact of each of these criteria to be used in the boundary determination. The criteria assessed as part of this research included, population density, emission criteria (industrial, mining, transport and domestic), topography and administrative boundaries. A further objective of the research was to combine all the criteria to produce a single indicator or value as to the air pollution impact potential of the area under consideration. This methodology was then applied in the South African context. The final objective of the research was to assess the results of the application of the methodology on the regulatory framework proposed by the AQA, at the national, provincial and local government levels.

7.2 Conclusions and Recommendations

The methodology has proved successful in the identification of areas with high air pollution impact potential in South Africa. This has allowed for a review of the boundaries proclaimed for the VTAPA and the HPA. In both cases significant revisions of the boundaries are recommended, however due to the controversial nature of these recommendations, it is proposed that these revisions are deferred until the five-yearly review phase of the priority area management plan. The results indicated the need to proclaim an additional two national priority areas. The first was the proposed Magaliesberg Priority Area, which covers the north-western areas of Gauteng and the eastern areas of the North-West. This area combines the high density residential, commercial and industrial areas of Gauteng with the high density mining and industrial areas of the North-West. However, it is recommended that further ambient air quality monitoring and research is required prior to the proclamation of this national priority area. The second new national priority area proposed is the Waterberg Priority Area. This proclamation is a proactive declaration based on the proposed industrial developments earmarked for this area. Due to extensive coal reserves in the area, the development of additional coal-fired power generation, a coal to liquid facility and other coal beneficiation projects are currently under consideration.

The research has identified six potential provincial priority areas. The provincial priority areas are associated with the major metropolitan centres in the country and their adjacent district municipalities. All of the proposed provincial priority areas, with the exception of the one proposed in Gauteng, require further ambient air quality monitoring and research prior to their proclamation. It is recommended that the City of Johannesburg / City of Tshwane provincial priority area be considered for immediate declaration.

The review of the district and local municipalities identified in Table 24 of the National Framework highlighted the conservative nature of the initial assessment. The review amended the classification of 33 of the local municipalities, with 32 being reclassified downwards and only one being reclassified upwards. This also highlighted the subjective nature of the initial assessment. It is recommended that the local municipalities identified in revised section of Table 6.19 be prioritised in terms of the roll out of the national ambient air quality monitoring network. This programme commences in 2010 and aims to expand the national ambient air quality monitoring network to high air pollution impact potential areas that currently have no or limited ambient air quality monitoring taking place. The objective of this network is to provide credible scientific information to guide air quality management in the country. It is also recommended that the municipalities identified in Table 6.1 be prioritised in terms of assistance for the development of their air quality management plans. This ensures that the limited financial and human resources assigned to air quality management are deployed in those areas with the greatest need.

7.3 Looking Forward

The methodology proposed by this research is considered part of an iterative approach to air quality management in South Africa. In order to fulfil the Constitutional right to an environment that is not harmful to health and well-being, immediate action is required to identify areas with potentially poor or poor air quality. This research proposes a methodology to identify areas with compromised air quality, in the absence of conventional methodologies. This allows for the limited air quality resources in South Africa to be deployed in those areas with the greatest need. As the national ambient air quality management network develops and long term ambient air quality monitoring records come available, this methodology will be replaced by those applied internationally. Phase II of the SAAQIS will see the development of the national emissions inventory which will also allow for the application of dispersion modelling as used in international methodologies. Phase II will commence in 2010 and is scheduled for completion by the end of 2012. This methodology is also suitable for application in other countries where long term ambient air quality data and comprehensive emission inventories are unavailable.

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Appendix 1 – Table 24 – National Framework

Table 24: Metropolitan and District Municipalities initially rated as having Poor or Potentially Poor Air Quality (an indicative assessment only)

Province	Metropolitan or District Municipality	Air Quality Rating	Reasoning
Northern Cape	Kgalagadi DM	Potentially Poor	Mining
Western Cape	West Coast DM	Poor	Industrial
	City of Cape Town MM	Poor	Urban
	Cape Winelands DM	Poor	Agriculture
	Eden DM	Potentially Poor	Urban and Industrial
Eastern Cape	Nelson Mandela MM	Poor	Urban
	Amatole DM	Potentially Poor	Urban
KwaZulu Natal	Ugu DM	Potentially Poor	Urban and Agriculture
	eThekwini MM	Poor	Urban and Industrial
	uMgungundlovu DM	Potentially Poor	Urban and Agriculture
	Uthukela DM	Potentially Poor	Urban and Agriculture
	iLembe DM	Potentially Poor	Urban and Agriculture
	Uthungulu DM	Poor	Industrial and Agriculture
	Amajuba DM	Potentially Poor	Urban and Agriculture
Mpumalanga	Ehlanzeni DM	Potentially Poor	Industrial
	Gert Sibande DM	Poor	Industrial
	Nkangala DM	Poor	Industrial
Gauteng	West Rand DM	Potentially Poor	Urban and Mining
	City of Johannesburg	Poor	Urban
	Sedibeng DM	Poor	Urban and Industrial
	Ekurhuleni DM	Poor	Urban and Industrial
	City of Tshwane	Potentially Poor	Urban
	Metsweding	Potentially Poor	Mining
North West	Bojanala Platinum DM	Poor	Mining
	Southern DM	Potentially Poor	Urban and Mining
Limpopo	Mopani DM	Potentially Poor	Mining
	Capricorn DM	Potentially Poor	Urban and Mining
	Waterberg DM	Potentially Poor	Industrial

Note – The original Table 24 only identified air pollution hot spots areas at the District Municipality level. It must also be noted that the original table omitted the Free State. Table 6.19 provides a corrected listing and provides detail at the local municipality level.

Appendix 2 – Table of Results

Province	Metro / District	Industry Rating	Mines	Pop Density	Domestic	Final Rating
Eastern Cape	Alfred Nzo	1	2	2	4	9
Eastern Cape	Ukhahlamba DM	1	1	1	2	5
Eastern Cape	Chris Hani DM	1	1	1	5	8
Eastern Cape	O.R. Tambo DM	1	1	3	6	11
Eastern Cape	Cacadu DM	1	1	1	2	5
Eastern Cape	Amatole DM	2	3	2	6	13
Eastern Cape	Nelson Mandela Bay Metro	5	6	7	5	23
Free State	Xhariep DM	1	1	1	1	4
Free State	Thabo Mofutsanyane DM	2	1	1	3	7
Free State	Lejweleputswa DM	2	2	1	2	7
Free State	Motheo DM	2	2	2	2	8
Free State	Fezile Dabi DM	3	2	1	2	8
Gauteng	Metsweding DM	2	4	1	1	8
Gauteng	West Rand DM	4	5	3	5	17
Gauteng	Sedibeng DM	5	4	3	4	16
Gauteng	City of Johannesburg Metro	6	6	8	5	25
Gauteng	City of Tshwane Metro	6	6	7	5	24
Gauteng	Ekurhuleni Metro	6	6	8	6	26
KwaZulu Natal	Umkhanyakude DM	1	2	1	5	9
KwaZulu Natal	Sisonke DM	1	1	1	4	7
KwaZulu Natal	Umzinyathi DM	1	2	2	4	9
KwaZulu Natal	Zululand DM	1	2	2	5	10
KwaZulu Natal	Uthukela DM	1	2	2	5	10
KwaZulu Natal	Amajuba DM	2	3	2	5	12
KwaZulu Natal	Uthungulu DM	3	4	3	6	16
KwaZulu Natal	Ugu DM	2	5	3	6	16
KwaZulu Natal	iLembe DM	2	4	3	6	15
KwaZulu Natal	uMgungundlovu DM	4	4	3	6	17
KwaZulu Natal	Ethekwini Metro	6	6	8	5	25
Limpopo	Capricorn DM	1	3	2	5	11
Limpopo	Greater Sekhukhune	1	3	2	6	12
Limpopo	Vhembe DM	2	2	2	5	11
Limpopo	Waterberg DM	2	1	1	2	6
Limpopo	Mopani DM	2	4	2	5	13
Mpumalanga	Ehlanzeni DM	5	4	2	5	16
Mpumalanga	Gert Sibande DM	5	2	1	5	13

Mpumalanga	Nkangala DM	5	4	2	6	17
North West	Ngaka Modiri Molema DM	2	2	1	3	8
North West	Dr Ruth Segomotsi Mompati DM	1	1	1	2	5
North West	Dr Kenneth Kaunda DM	3	3	1	2	9
North West	Bojanala Platinum DM	5	4	2	5	16
Northern Cape	Kgalagadi DM	1	1	1	1	4
Northern Cape	Pixley ka Seme DM	1	1	1	1	4
Northern Cape	Namakwa DM	1	1	1	1	4
Northern Cape	Siyanda DM	1	1	1	1	4
Northern Cape	Frances Baard DM	1	4	1	2	8
Western Cape	Central Karoo DM	1	1	1	1	4
Western Cape	Overberg DM	1	2	1	1	5
Western Cape	West Coast DM	2	2	1	1	6
Western Cape	Eden DM	3	2	1	2	8
Western Cape	Cape Winelands DM	3	2	1	2	8
Western Cape	City of Cape Town	6	6	8	2	22

Province	District Municipalities	Local Municipalities	Pop Density	Industry Rating	Mines	Domestic Rating	Final Rating
Eastern Cape	Cacadu	Camdeboo	1	1	2	1	5
		Blue Crane Route	1	1	2	1	5
		Makana	1	1	3	1	6
		Baviaans	1	1	1	1	4
		Sunday's River	1	1	1	1	4
		Ndlambe	1	1	5	2	9
		Ikwezi	1	1	2	1	5
		Kouga	1	1	5	1	8
		Kou Kamma	1	1	1	1	4
	Amathole	Mbashe	2	1	1	6	10
		Buffalo City	5	2	6	6	19
		Amahlati	1	1	3	3	8
		Great Kei	1	1	3	2	7
		Mnquma	2	1	3	6	12
		Mgqushwa	1	1	1	4	7
		Nxuba	1	1	1	1	4
		Nkonkobe	1	1	3	3	8
	Chris Hani	Inxuba Yethemba	1	1	2	1	5
		Tsolwana	1	1	2	1	5
		Inkwanca	1	1	1	1	4
		Lukhanji	1	1	3	2	7
		Emalahleni	1	1	1	3	6
		Sakhisizwe	1	1	1	3	6
		Engcobo	2	1	1	4	8
		Intsika Yethu	2	1	1	4	8
	Ukhahlamba	Elundini	1	1	3	2	7
		Senqu	1	1	1	2	5
		Gariep	1	1	1	1	4
		Maletswai	1	1	2	1	5
	OR Tambo	Mbizana	3	1	1	6	11
		Ngquza	3	1	1	6	11
		Ntabankulu	2	1	1	5	9
		Port St Johns	3	1	1	6	11
		Mhlontlo	2	1	1	4	8
		King Sabata Dalindyebo	3	1	1	7	12
		Nyandeni	3	1	3	6	13

	Alfred Nzo	Umzimvubu	2	1	1	6	10
		Matatiele	2	1	4	4	11
	Nelson Mandela Bay Metro	n/a	6	5	6	7	24
Free State	Xhariep	Letseweng	1	1	2	1	5
		Mohokare	1	1	1	1	4
		Kopanong	1	1	1	1	4
	Motheo	Naledi	1	1	1	1	4
		Mantsopa	1	1	1	1	4
		Mangaung	3	2	4	3	12
	Lejweleputswa	Masilonyana	1	1	2	1	5
		Tokologo	1	1	2	1	5
		Tswelopele	1	1	2	1	5
		Nala	1	1	1	1	4
		Matjhabeng	2	2	5	2	11
	Thabo Mofutsanyane	Setsoto	1	1	2	2	6
		Dihlabeng	1	1	3	1	6
		Maulti a Phofong	2	1	3	4	10
		Phumelela	1	1	1	1	4
		Nketoana	1	1	1	1	4
	Fezile Dabi	Moqhaka	1	1	2	1	5
		Ngwathe	1	1	2	1	5
		Metsimaholo	2	2	5	3	12
		Mafube	1	1	1	1	4
Gauteng	Sedibeng	Emfuleni	6	4	6	6	22
		Lesedi	1	1	1	2	5
		Midvaal	1	2	3	1	7
	Metsweding	Kungwini	1	2	5	1	9
		Nokeng tsa Taemane	1	1	1	1	4
	West Rand	Randfontein	4	1	6	3	14
		Westonaria	4	1	6	4	15
		Mogale City	4	2	6	5	17
		Merafong City	3	1	5	4	13
	Ekurhuleni Metro		7	6	6	7	26
	City of Johannesburg Metro		7	6	6	7	26
	City of Tshwane Metro		6	6	6	7	25
	Ugu	Vulamehlo	2	1	1	5	9
		uMdoni	5	1	6	6	18

		uMuziwabantu	2	1	1	5	9
		Hibiscus Coast	5	1	6	6	18
		Ezinqoleni	2	1	5	6	14
		Umzumbe	4	1	1	6	12
	Umgungundlovu	uMshwathi	2	1	1	4	8
		Richmond	2	1	1	3	7
		The Msunduzi	6	3	6	6	21
		Mkhambathini	2	1	5	4	12
		Impendle	1	1	1	2	5
		Mpofana	1	1	1	1	4
		uMngeni	1	1	3	2	7
	Uthukela	Okhahlamba	1	1	1	3	6
		Emnambithi-Ladysmith	2	1	3	2	8
		Indaka	3	1	1	6	11
		Inbabazane	3	1	1	6	11
		Umtshezi	1	1	3	2	7
	Umzinyathi	Endumeni	1	1	5	1	8
		Nquthu	2	1	3	4	10
		Umvoti	1	1	1	2	5
		Msinga	2	1	1	4	8
	Amajuba	Newcastle	4	2	5	6	17
		eMadlangeni	1	1	2	1	5
		Dannhauser	2	1	3	5	11
KwaZulu Natal	Zululand	uPhongolo	1	1	1	2	5
		Abaqulusi	1	1	4	2	8
		eDumbe	1	1	3	3	8
		Ulundi	2	1	3	4	10
		Nongoma	2	1	1	5	9
	Umkhanyakude	Umhlabuyalingana	1	1	1	3	6
		The Big Five False Bay	1	1	1	2	5
		Jozini	2	1	3	4	10
		Hlabisa	3	1	5	6	15
		Mtubatuba	2	1	1	2	6
	uThungulu	Mbonambi	2	1	4	4	11
		Nkandla	2	1	1	4	8
		uMhlathuze	5	2	6	4	17
		Ntambanana	2	1	1	5	9

		Umlalazi	2	1	3	5	11
		Mtonjaneni	1	1	1	3	6
	iLembe	Ndwedwe	3	1	1	6	11
		Maphumulo	3	1	1	6	11
		The KwaDukuza	5	1	6	3	15
		eDondakusuka	4	1	5	6	16
	Sisonke	Umzimkulu	1	1	1	1	4
		Ingwe	2	1	1	3	7
		Kwa Sani	1	1	1	1	4
		Ubuhlebezwe	2	1	3	4	10
		Greater Kokstad	1	1	2	2	6
	eThekwini Metro		7	6	6	7	26
Limpopo	Mopani	Maruleng	1	1	1	2	5
		Greater Giyani	2	1	3	5	11
		Greater Tzaneen	3	1	5	6	15
		Ba-Phalaborwa	1	1	5	2	9
		Greater Letaba	3	1	4	6	14
	Vhembe	Musina	1	1	2	1	5
		Thulamela	4	1	5	7	17
		Makhado	2	1	3	3	9
		Mutale	1	1	1	2	5
	Capricorn	Blouberg	1	1	1	2	5
		Molemole	1	1	1	2	5
		Polokwane	3	1	5	6	15
		Aganang	2	1	1	5	9
		Lepele-Nkumpi	2	1	3	3	9
	Waterberg	Thabazimbi	1	1	2	1	5
		Modimolle	1	1	2	1	5
		Mogalakwena	1	1	5	3	10
		Bela Bela	1	1	3	1	6
		Mookgopong	1	1	1	1	4
		Lephalale	1	1	2	1	5
	Greater Sekhukhune	Greater Marble Hall	2	1	3	3	9
		Elias Motsoaledi	2	1	3	6	12
		Makhudutamaga	3	1	1	6	11
		Fetagomo	2	1	1	5	9
		Greater Tubatse	2	1	5	4	12

Mpumalanga	Gert Sibande	Albert Luthuli	1	1	4	2	8
		Msukaligwa	1	2	3	2	8
		Mkhondo	1	2	3	2	8
		Pixley ka Seme	1	1	2	2	6
		Dipaleseng	1	1	2	1	5
		Govan Mbeki	2	2	5	5	14
		Lekwa	1	1	2	2	6
	Nkangala	Delmas	1	1	5	3	10
		Dr JS Moroka	4	1	1	6	12
		Emalahleni	3	4	6	4	17
		Steve Tshwete	1	2	5	3	11
		Emakhazeni	1	1	3	1	6
		Thembisile	3	1	1	6	11
	Ehlanzeni	Bushbuckridge	4	1	1	6	12
		Thaba Chweu	1	2	3	1	7
		Mbombela	3	3	5	5	16
		Umjindi	1	1	5	1	8
		Nkomazi	3	1	3	5	12
North West	Bojanala Platinum	Moretele	3	1	1	6	11
		Madibeng	2	3	5	2	12
		Rustenburg	3	3	5	3	14
		Kgetlengrivier	1	1	2	1	5
		Moses Kotane	1	1	3	2	7
	Ngaka Modiri Molema	Tswaing	1	1	1	2	5
		Mafikeng	2	1	3	2	8
		Ratlou	1	1	1	2	5
		Ditsobotla	1	1	5	1	8
		Ramotshere Moiloa	1	1	2	1	5
	Dr Ruth Segomotsi Mompati	Kagisano	1	1	1	1	4
		Molopo	1	1	2	1	5
		Lekwa-Teemane	1	1	3	1	6
		Greater Taung	1	1	1	2	5
		Naledi	1	1	2	1	5
		Mamusa	1	1	3	1	6
	Dr Kenneth Kuanda	Ventersdorp	1	1	3	1	6
		Tlokwe	1	1	4	1	7
		City of Matlosana	3	2	5	3	13

		Maquassi Hills	1	1	3	1	6
Northern Cape	Kgalagadi	Ga-Segonyana	1	1	3	1	6
		Moshaweng	1	1	1	1	4
		Gamagara	1	1	2	1	5
	Namakwa	Kamiesberg	1	1	2	1	5
		Karoo Hoogland	1	1	1	1	4
		Nama Khoi	1	1	2	1	5
		Richterveld	1	1	2	1	5
		Khai-Ma	1	1	2	1	5
		Hantam	1	1	2	1	5
	Pixley Ka Seme	Ubuntu	1	1	1	1	4
		Siyathemba	1	1	2	1	5
		Siyancuma	1	1	1	1	4
		Thembelihle	1	1	2	1	5
		Umsobomvu	1	1	1	1	4
		Emthanjeni	1	1	2	1	5
		Renosterberg	1	1	1	1	4
		Kareeberg	1	1	1	1	4
	Siyanda	Mier	1	1	1	1	4
		Kgatelopele	1	1	1	1	4
		!Kai! Garib	1	1	2	1	5
		Khara Heis	1	1	4	1	7
		Tsantsabane	1	1	2	1	5
		!Kheis	1	1	1	1	4
	Frances Baard	Phokwane	1	1	4	1	7
		Dikgatlong	1	1	5	1	8
		Magareng	1	1	3	1	6
		Sol Plaatjie	3	1	6	3	13
	City of Cape Town		6	6	6	6	24
	West Coast	Matzikama	1	1	3	1	6
		Cedarberg	1	1	2	1	5
		Swartland	1	1	5	1	8
		Saldanha Bay	1	1	5	1	8
		Bergrivier	1	1	2	1	5
	Cape Winelands	Witzenberg	1	1	3	1	6
		Drakenstein	3	1	5	2	11
		Stellenbosch	3	1	5	2	11

Western Cape		Breede Valley	1	1	4	1	7
		Breede Rivier / Winelands	1	1	3	1	6
	Overberg	Theewaterskloof	1	1	4	1	7
		Overstrand	1	1	4	1	7
		Cape Aghulas	1	1	3	1	6
		Swellendam	1	1	3	1	6
	Eden	Kannaland	1	1	2	1	5
		Hessequa	1	1	3	1	6
		Mossel Bay	1	1	5	1	8
		George	3	2	5	2	12
		Oudtshoorn	1	1	3	1	6
		Bitou	1	1	3	1	6
		Knysna	1	1	5	1	8
	Central Karoo	Laingsburg	1	1	2	1	5
		Prince Albert	1	1	1	1	4
		Beaufort West	1	1	2	1	5