*National Environmental Standards for Air Quality: Implementation*

# Review and Gap Analysis of $PM_{10}$ Monitoring in New Zealand

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*(This document is available for download as a pdf file from www.niwa.co.nz/ncces/)*

# Executive Summary

The objective of this research is to "Complete a gap analysis of existing monitoring, with recommendations for enhancements". One major objective is to hold a workshop for end-users to assess the upgrade requirements for regional monitoring networks. The workshop will aim to:

- Present gap analysis of current PM monitoring networks
- Make recommendations for PM monitoring network enhancement
- Raise PM monitoring issues that need to be addressed
- Gain feedback from stakeholders on further research needs

This report lays the foundations for the workshop by providing information and recommendations to be considered and discussed. It is anticipated that the ultimate outcome of the workshop will be to allow end-users to:

- Assess the adequacy of their $PM_{10}$ monitoring network in respect to NES requirements; and
- Determine what (if any) upgrades to their regional monitoring network are required

It is anticipated that the workshop will be held in late September 2005. This report will be revised and finalised using the feedback generated at the end-user workshop. The format of the research is based around LAMAs or "Local Air Management Areas" that have been used previously. These correspond in many instances to the 'airsheds' that have been defined for the NEW implementation. This report is structured as:

**Part 1. Monitoring Network Gap Identification**

The aims of Part 1 are to provide an overview on the "state" of the national monitoring network of Category 1 LAMAs. Part 1:

- Presents a region-by-region summary of past, current and planned $PM_{10}$ monitoring
- Identifies the Category 1 LAMAs within each region which have little or no $PM_{10}$ data

**N.B.** Part 1 of the report will benefit from input and review from Regional Councils. This report should NOT be considered a comprehensive review and definitive assessment of the state of the national $PM_{10}$ monitoring network as it currently stands or of future plans.

**Part 2. Monitoring Network Enhancement**

Part 2 aims to provide information, which will allow end users to efficiently and effectively enhance their $PM_{10}$ monitoring network to meet the requirements of the NES. Part 2:

- Presents a methodology to prioritise monitoring of Category 1 LAMAs which are not yet monitored.
- Makes recommendations on the optimal number and siting of PM monitors within a LAMA.
- Makes suggestions on how to manage $PM_{10}$ monitoring in Category 1 LAMAs that are not currently monitored nor planned to be.

**Part 3. Knowledge Gaps**

The aim of Part 3 is to highlight and discuss our current knowledge (as opposed to network) gaps in $PM_{10}$ monitoring. Part 3 considers:

- Different methods of monitoring PM
- $PM_{2.5}$ in urban areas
- Measuring particle numbers rather than particle mass
- Particulate matter component composition and source apportionment
- Monitoring background and/or natural concentrations of PM

## Document Structure and Content



CAVEAT
This report attempts to provide a substantial degree of information and new concepts to enhance the effectiveness of $PM_{10}$ monitoring in New Zealand in order to meet the Air Quality Standards. It relies on having a great deal of up-to-date information on Council monitoring programmes – but the authors note that some of this is incomplete. The research also covers some exploratory techniques, designed to inform the debate rather than be a defined research outcome at this stage.

# Introduction:

The Monitoring and Network Design research is part of the Foundation for Research Science and Technology's (FRST) Protecting New Zealand's Clean Air Programme (Contract number C01X0405). This research aims to develop methods and tools to design monitoring networks and measurement systems that meet the requirements of the National Environmental Standards (NES) as effectively as possible.

The Monitoring and Network Design objective's outputs will provide information to improve the effectiveness and efficiency of the national and regional air quality monitoring systems that provide the fundamental data on air quality and compliance with the Standards. Many areas of the country do not have adequate monitoring information in order to achieve the requirements of the Standards, so the focus is on ensuring that the monitoring is representative and cost-effective, especially for smaller regions without large resources.

The research contributes to the over-riding programme outcomes by ensuring that adequate information is available on the air quality in regions that might be affected by exceedences, and on progress of implementation and mitigation strategies towards achieving better air quality.

The specific output for this phase of the research is to hold a workshop for end-users to assess the upgrade requirements for regional monitoring networks.

The workshop will aim to:

- Present gap analysis of current PM monitoring networks
- Make recommendations for PM monitoring network enhancement
- Raise PM monitoring issues that need to be addressed
- Gain feedback from stakeholders on where to from here.

This report will lay the foundations for the workshop by providing information and recommendations to be considered and discussed. It is anticipated that the ultimate outcome of the workshop will be to allow end-users to:

- Assess the adequacy of their $PM_{10}$ monitoring network in respect to NES requirements; and
- Determine what (if any) upgrades to their regional monitoring network are required

It is anticipated that the workshop will be held in late September 2005. This report will be revised and be finalised using the feedback generated at the end-user workshop.

To contribute toward the research's specific outputs this report will be structured as described below.

**Part 1. Monitoring Network Gap Identification**

The aims of Part 1 are to provide an overview on the "state" of the national monitoring network of Category 1 LAMAs.

Part 1 will:

- Present a region-by-region summary of past, current and planned $PM_{10}$ monitoring
- Identify the Category 1 LAMAs within each region which have little or no $PM_{10}$ data

Part 1 of this draft report is principally based on two sources:

- Information and data which was readily available from Regional Councils via their websites
- Knowledge of the authors.

**PLEASE NOTE CAREFULLY**

Part 1 of the draft report will obviously benefit from input and review from Regional Councils. Specifically Part 1 can be improved in relation to monitoring which occurred in 2004 and 2005 (which at the time of writing may have not been reported on) and in relation to sites where future monitoring is planned. For these reasons Part 1 is should NOT be considered a comprehensive review and definitive assessment of the state of the national $PM_{10}$ monitoring network. However, it is anticipated that Part 1 of this report and the associated end-user workshop, will provide the foundations for a comprehensive review to occur, and be reported on when this document is finalised.

**Part 2. Monitoring Network Enhancement**

The aim of Part 2 is to provide information, which will allow end users to efficiently and effectively enhance their $PM_{10}$ monitoring network to meet the requirements of the NES.

Part 2 will:

- Present a methodology to prioritise the monitoring of Category 1 Lama's which have little or no $PM_{10}$ data
- Make recommendations on to how collect representative data by determining the optimal number and siting of PM monitors within a LAMA.
- Make a number suggestions on how to manage $PM_{10}$ monitoring in Category 1 LAMAs that are not currently nor planned to be monitored

**Part 3. Knowledge Gaps**

The aim of Part 3 is to highlight and discuss our current knowledge (as opposed to network) gaps in $PM_{10}$ monitoring.

Part 3 considers:

- Different methods of monitoring PM
- $PM_{2.5}$ in urban areas
- Measuring particle numbers rather than particle mass
- Particulate matter component composition and source apportionment
- Monitoring background and/or natural concentrations of PM

Section 3 will:

- Briefly outline the issue and put it into the New Zealand context
- Describe what NZ data exists
- Make some preliminary recommendations on how the Programme may to move forward to developing and eventually resolving the issue

# Part 1. Monitoring Network Gap Identification

## 1.1 Northland Region

Figure 1.1 shows the proposed LAMA categories and Particulate Monitoring sites for the Northland Region.

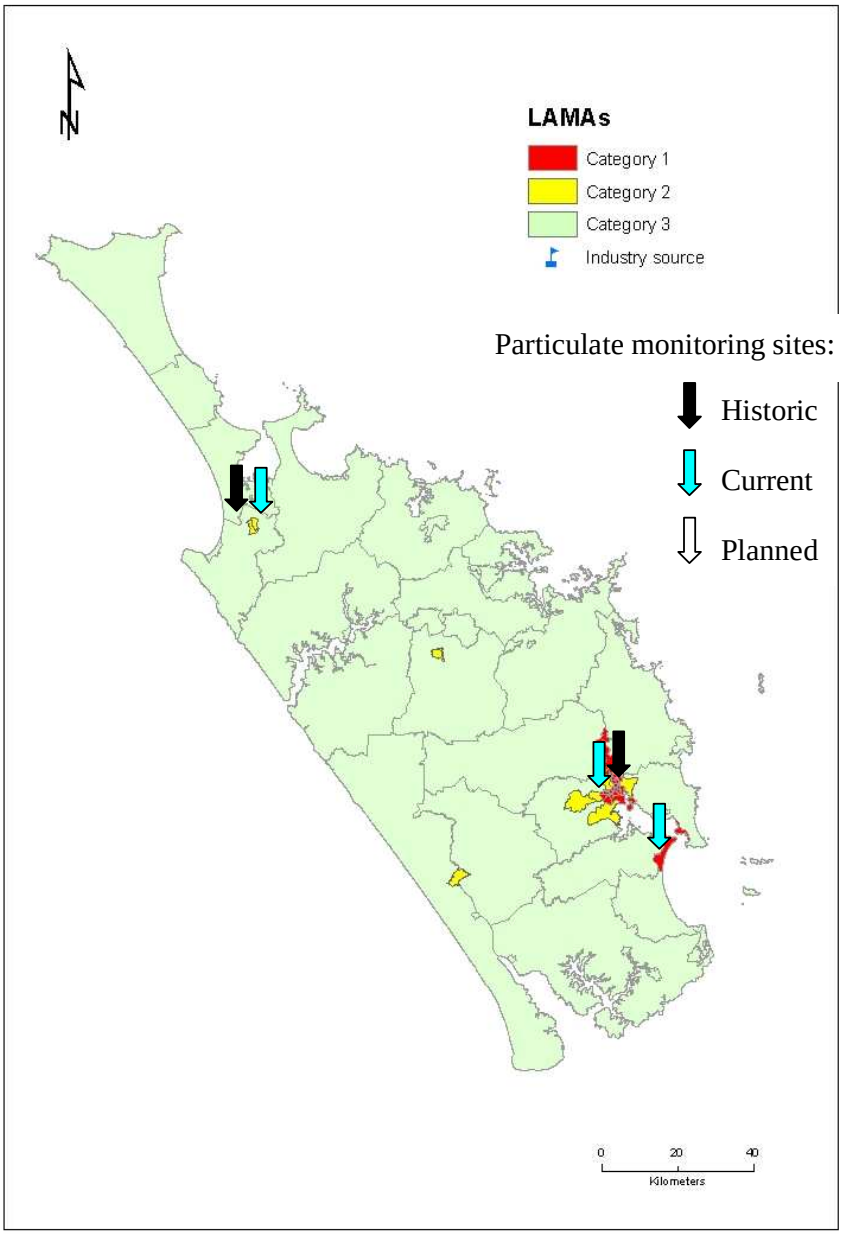


Figure 1.1 LAMA categories and Particulate Monitoring sites for the Northland Region.

The suggested LAMAs for Northland Region are:

Category 1 **Bream Bay (both sides of harbour)**
Category 1 **Central Whangarei / Kamo**

Category 2 Outer Whangarei
Category 2 Dargaville
Category 2 Kaikohe
Category 2 Kaitaia

Category 3 All the rest

Thus there are 2 Category 1, 4 Category 2, and 1 Category 3 LAMAs. Table 1.1 provides a summary of past, current and planned $PM_{10}$ monitoring for the Northland Region.

Table 1.1 $PM_{10}$ monitoring undertaken in the Northland Region.

| Site | Lama Category | Dates of monitoring | Method of monitoring | Number of Exceedences recorded | Source of Information |
|---|---|---|---|---|---|
| Kaitaia (Awanui Straight) | 2 | Dec 02 to Apr 04 | High Volume | 0 | NRC 2003<br>NRC 2004 |
| Kaitaia (Donald Road) | 2 | Mar 03 to present | GRIMM | 0 | NRC (Personal communication) |
| Whangarei (Robert Street) | 1 | Mar 00 to Jul 01 | High Volume | 1 | NRC 2002a<br>NRC 2002b |
| Whangarei (Water Street) | 1 | Aug 04 to Present | High Volume (1 day in 3) | 0 | NRC (Personal communication) |
| Marsden Point (Rama Road) | 1 | Mar 03 to present | High Volume | 0 | NRC (Personal communication) |

The information contained in Table 1.1 identifies:

- **No**

Category 1 LAMAs as a potential gap in the Northland $PM_{10}$ monitoring network.

*Sources of information*


1) *NRC 2004*

*Northland Regional Council Annual Environmental Monitoring Report 2003-2004: Air* *http://www.nrc.govt.nz/reports.and.news/annual.environmental.monitoring/2003-2004/air.shtml*

2) *NRC 2003*

*Northland Regional Council Annual Environmental Monitoring Report 2002-2003: Chapter 1 Air*

*http://www.nrc.govt.nz/reports.and.news/annual.environmental.monitoring/2002-2003/AMR_AIR%20QUALITY.pdf*

3) *NRC 2002a*

*State of the Environment Report 2002:: Chapter 1 Air*

*http://www.nrc.govt.nz/special/soe.2002/air/index.shtml*

4) *NRC 2002b*

*Northland Regional Council Annual Environmental Monitoring Report 2001-2002: Chapter 1 Air*

*http://www.nrc.govt.nz/reports.and.news/annual.environmental.monitoring/2001-2002/Chapter%20One%20-%20Air%20Quality.pdf*

## 1.2 Auckland Region

Figure 1.2 shows the proposed LAMA categories and Particulate Monitoring sites for the Auckland Region.

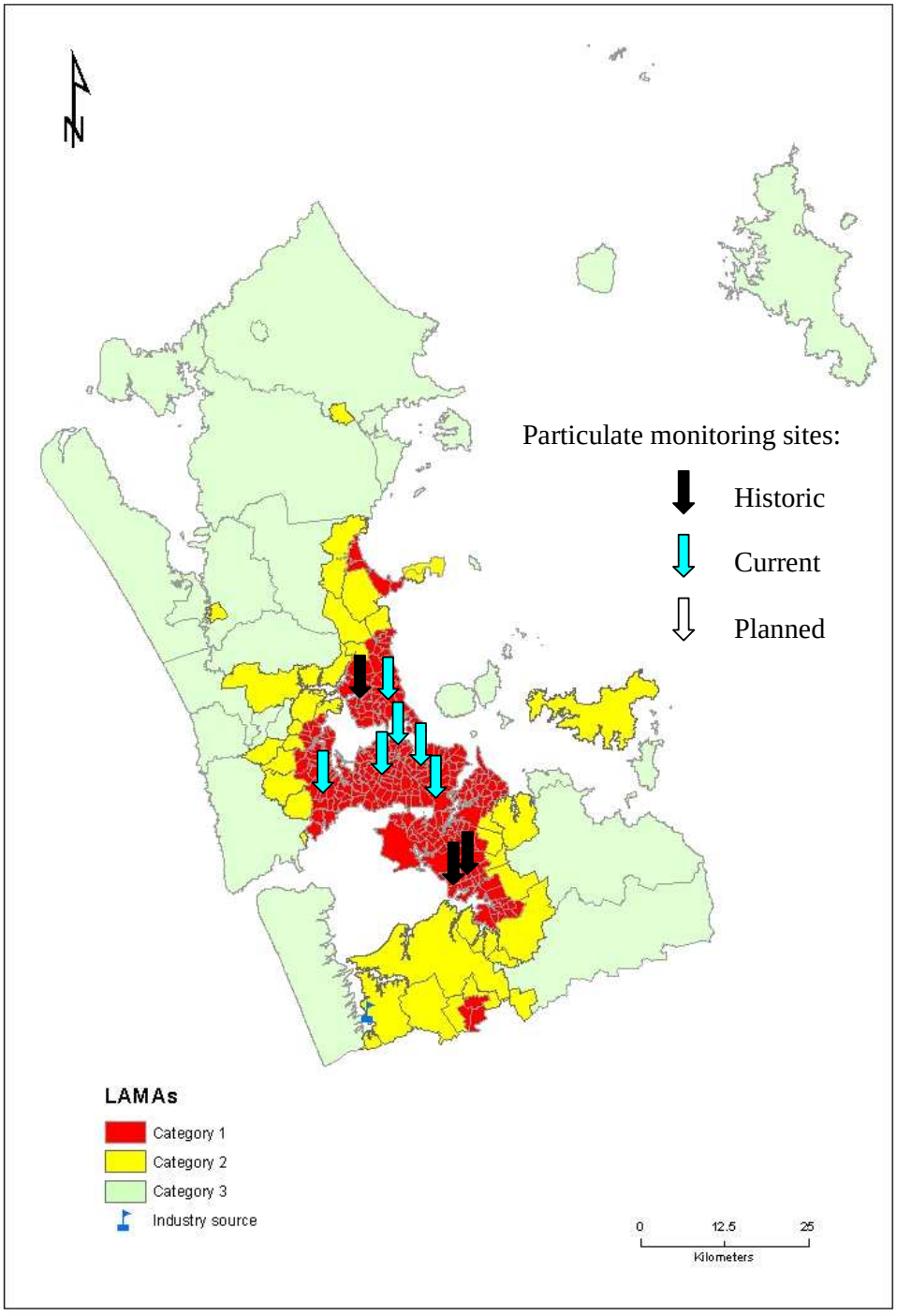


Figure 1.2 LAMA categories and Particulate Monitoring sites for the Auckland Region.

In summary, the suggested LAMAs for Auckland Region are:

Category 1 **Greater Auckland Central (Auckland City, North Shore City, bulk of Waitakere City, bulk of Manukau City)**
Category 1 **East North Shore**
Category 1 **Pukekohe**
Category 1 **Orewa**

Category 2 Waiheke Island
Category 2 South and East Manukau, to Central Franklin
Category 2 Central Waitakere, to West North Shore, to Whangaparaoa, to East Rodney
Category 2 Helensville
Category 2 Warkworth

Category 3 All the rest

Thus there are 4 Category 1, 5 Category 2, and 1 Category 3 LAMAs

Table 1.2 provides a summary of past, current and planned $PM_{10}$ monitoring for the Auckland Region.

Table 1.2 $PM_{10}$ monitoring undertaken in the Auckland Region.

| Site | Lama Category | Dates of monitoring | Method of monitoring | Number of Exceedences recorded | Source of Information |
|---|---|---|---|---|---|
| Queen Street | 1 | Dec 98 to present | Partisol | 0<br>2 –1999<br>2 – 2000<br>1 - 2001 | MfE 2003<br>ARC 2003 |
| Khyber Pass | 1 | Mar 98 to present | Partisol | 2 – 1998<br>1 – 1999<br>2 – 2000<br>1 – 2001<br>3 - 2002 | MfE 2003 |
| Takapuna | 1 | Nov 97 to Apr 00 | High Volume | 1 – 1997<br>2 -2001 | MfE 2003<br>ARC 2003 |
| Takapuna | 1 | Nov 95 to Apr 99 | TEOM | 0 | MfE 2003 |
| Takapuna | 1 | Apr 02 to present | Partisol | 0 | ARC 2003 |
| Henderson | 1 | 2001 - 2002 | Mini-Vol | 1- 2001 | ARC 2003 |
| Henderson | 1 | Jul 98 to present | Partisol | 1 – 1999 | MfE 2003 |
| Henderson | 1 | 2003 | Beta Gauge | 2 - 2003 | ARC 2003 |
| Glen Eden | 1 | 2001 - 2002 | Mini-vol | 1 - 2001 | ARC 2003 |
| Penrose | 1 | Apr 94 to present | High Volume | 3 – 1994<br>2 – 1995<br>3 – 1997<br>2 – 1999<br>1 – 2000<br>2 – 2001 | MfE 2003 |
| Penrose | 1 | 2002 – 2003 | Partisol | 1 -2003 | ARC 2003 |
| Penrose | 1 | July 00 to Mar 03 | TEOM | 1 - 2001 | ARC2003 |
| Penrose | 1 | 2003 to present | Beta Gauge | 2 - 2003 | ARC 2003 |
| Mount Eden | 1 | Feb 97 to Dec 02 | Partisol | 0<br>1 - 2001 | MfE 2003<br>ARC 2003 |
| Mount Eden | 1 | July 02 to present | Beta Gauge | 3 - 2003 | ARC 2003 |
| Galvin Street | | May 03 to present | Partisol | 1 - 2003 | ARC 2003 |

The information contained in Table 1.2 identifies the:

- **Pukekohe**
- **Orewa**
- **And perhaps Manukau City**

Category 1 LAMAs as a potential gap in the Auckland $PM_{10}$ monitoring network.

*Sources of information*


*1) MfE 2003*

*Monitoring of PM10 in New Zealand*

*http://www.mfe.govt.nz/publications/air*

*2) ARC 2004*

*ARC Air quality data CD*

*3) ARC 1997*

*Ambient Air Quality: Monitoring Results for the Auckland Region 1964-1995. Technical Publication Number 88.*

http://arc.govt.nz/arc/index.cfm?8025CB09-B4DD-49B7-88A7-3A332F2269B5

## 1.3 Waikato Region

Figure 1.3 shows the proposed LAMA categories and Particulate Monitoring sites for the Waikato Region

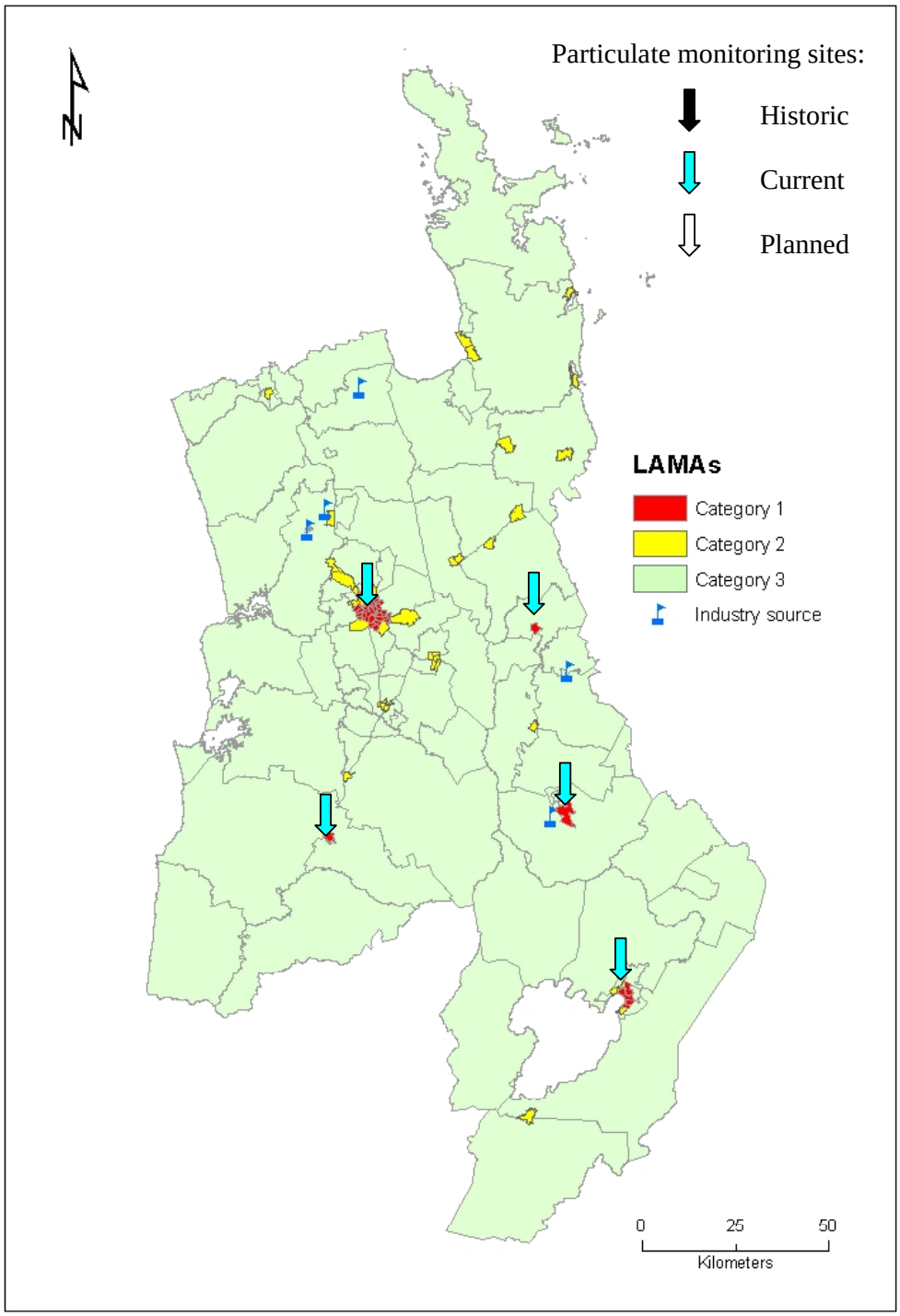


Figure 1.3 LAMA categories and Particulate Monitoring sites for the Waikato Region.

In summary, the suggested LAMAs for the Waikato Region are:

Category 1 **Hamilton**
Category 1 **Taupo**
Category 1 **Tokoroa**
Category 1 **Te Kuiti**
Category 1 **Matamata***
* Based on potential for exceedences, considered marginal

Other areas that may be considered for air quality management purposes are:

Category 2 Outer Hamilton
Category 2 Outer Taupo
Category 2 Cambridge
Category 2 Te Awamutu
Category 2 Waihi
Category 2 Putaruru
Category 2 Morrinsville
Category 2 Waitoa
Category 2 Te Aroha
Category 2 Paeroa
Category 2 Thames
Category 2 Whangamata
Category 2 Whitianga
Category 2 Huntly
Category 2 Tuakau
Category 2 Turangi
Category 2 Otorohanga

Category 3 All the rest

Thus there are 5 Category 1, 17 Category 2, and 1 Category 3 LAMAs

Table 1.3 provides a summary of past, current and planned $PM_{10}$ monitoring for the Waikato Region.

Table 1.3 $PM_{10}$ monitoring undertaken in the Waikato Region.

| Site | Lama Category | Dates of monitoring | Method of monitoring | Number of Exceedences recorded | Source of Information |
|---|---|---|---|---|---|
| Hamilton | 1 | May 98 to Dec 04 | TEOM | 7 | EW 2004a<br>EW 2004b |
| Taupo | 1 | Nov 01 to Dec 04 | Partisol | 25 | EW 2004a<br>EW 2004b |
| Tokora | 1 | Feb to Aug 99<br>Mar 03 –Dec 04 | Beta Gauge | 87 | EW 2004a<br>EW 2004b |
| Te Kuiti | 1 | Apr to Nov 98<br>May 03 to Dec 04 | Beta Gauge | 9 | EW 2004a<br>EW 2004b |
| Matamata | 1 | Began 2005 | | NA | |

The information contained in Table 1.3 identifies:

- **No**

Category 1 LAMAs as potential gaps in the Waikato $PM_{10}$ monitoring network.

*Sources of information*


*1) EW 2004a*

*Air Quality Monitoring 2003 Environment Waikato*

*http://www.ew.govt.nz/publications/technicalreports/tr0427.htm*

*2) EW 2004b*

*Fine Particles in the Air*

*http://ew.govt.nz/enviroinfo/indicators/air/quality/air1/keypoints.htm*

*3) MfE 2003*

*Monitoring of PM10 in New Zealand*

*http://www.mfe.govt.nz/publications/air*

## 1.4 Bay of Plenty Region

Figure 1.4 shows the proposed LAMA categories and Particulate Monitoring sites for the Bay of Plenty Region.

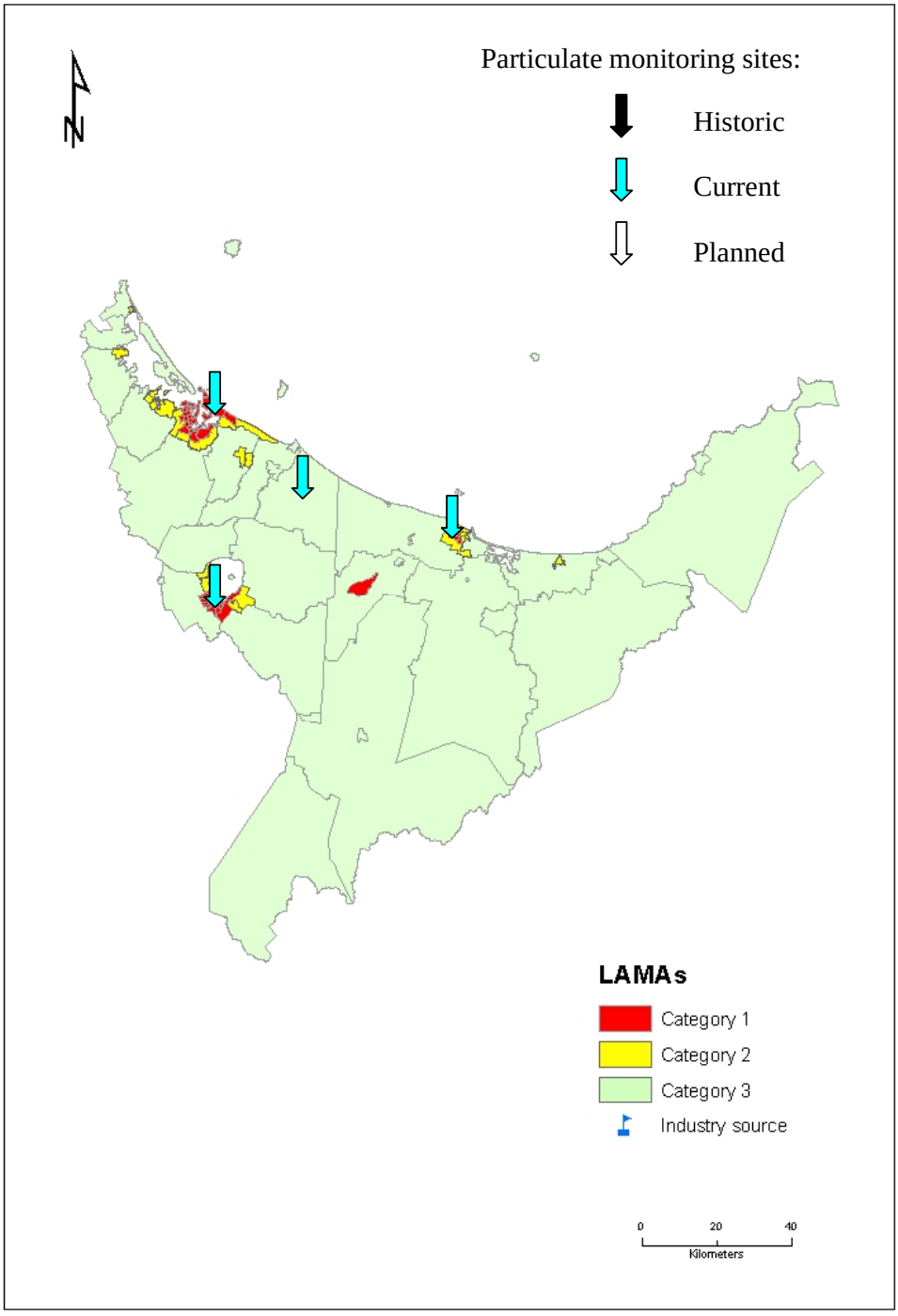


Figure 1.4 LAMA categories and Particulate Monitoring sites for the Bay of Plenty Region.

In summary, the suggested LAMAs for the Bay of Plenty Region are:

Category 1 **Tauranga / Mt Manganui**
Category 1 **Rotorua**
Category 1 **Kawerau**
Category 1 **Whakatane***
* Marginal due to small size and exposure to winds

Other areas that may be considered for air quality management purposes are:
Category 2 Outer Tauranga to Katikati
Category 2 East Rotorua
Category 2 West Rotorua
Category 2 Te Puke
Category 2 Pongakawa
Category 2 Opotoki

Category 3 All the rest

Thus there are 4 Category 1, 6 Category 2, and 1 Category 3 LAMAsThus there are 2 Category 1, 4 Category 2, and 1 Category 3 LAMAs.

Table 1.4 provides a summary of past, current and planned $PM_{10}$ monitoring for the Bay of Plenty Region.

Table 1.4 $PM_{10}$ monitoring undertaken in the Bay of Plenty Region.

| Site | Lama Category | Dates of monitoring | Method of monitoring | Number of Exceedences recorded | Source of Information |
|---|---|---|---|---|---|
| Rotorua (traffic) Fenton Street | 1 | Dec 98 to Feb 99 and July 99 to Jan 00 | TEOM | 5 | EBOP 1999 EBOP 2004a |
| Rotorua (residential) Pererika Street | 1 | 98 to 03 | TEOM | 1 | EBOP 1999 EBOP 2004a |
| Tauranga (traffic) Marsh Street | 1 | Mar 00 to Feb 01 and Nov 02 to Feb 03 | TEOM | 2 | EBOP 2004b |
| Tauranga (residential) Otumoetei Road | 1 | 97 to 03 | TEOM | 0 | EBOP 1999 |
| Whakatane (residential) | 1 | 97 to 03 | Partisol | 1 | EBOP 1999 EBOP 2004a |
| Pongakawa (background) | 3 | 97 to 03 | Partisol | 0 | EBOP 1999 EBOP 2004a |

The information contained in Table 1.4 identifies the:

- **Kawerau**

Category 1 Lama as a potential gap in the Bay of Plenty $PM_{10}$ monitoring network.

*Sources of information*


*1) EBOP 2004a*

*Air Natural Environmental Regional Monitoring Network: $PM_{10}$* http://ebop.govt.nz/Air/Monitoring/PM10/Particulate-PM10.asp

*2) EBOP 2004b*

*Bay Trends 2004. State of Bay of Plenty Environment 2004*

http://ebop.govt.nz/publications/main/html/main.html

*3) MfE 2003*

*Monitoring of PM10 in New Zealand*
*http://www.mfe.govt.nz/publications/air*
*4) EBOP 2002*
*State of the Environment Report 2001*
*http://ebop.govt.nz/media/pdf/soer2001%20part%20ii.pdf*
*5) EBOP 1999*
*Natural Environment Regional Monitoring Network (NERMN) Air Monitoring*
*http://ebop.govt.nz/media/pdf/reports/1999nermnairmonitoring.pdf*

## 1.5 Gisborne Region

Figure 1.5 shows the proposed LAMA categories and Particulate Monitoring sites for the Gisborne Region.

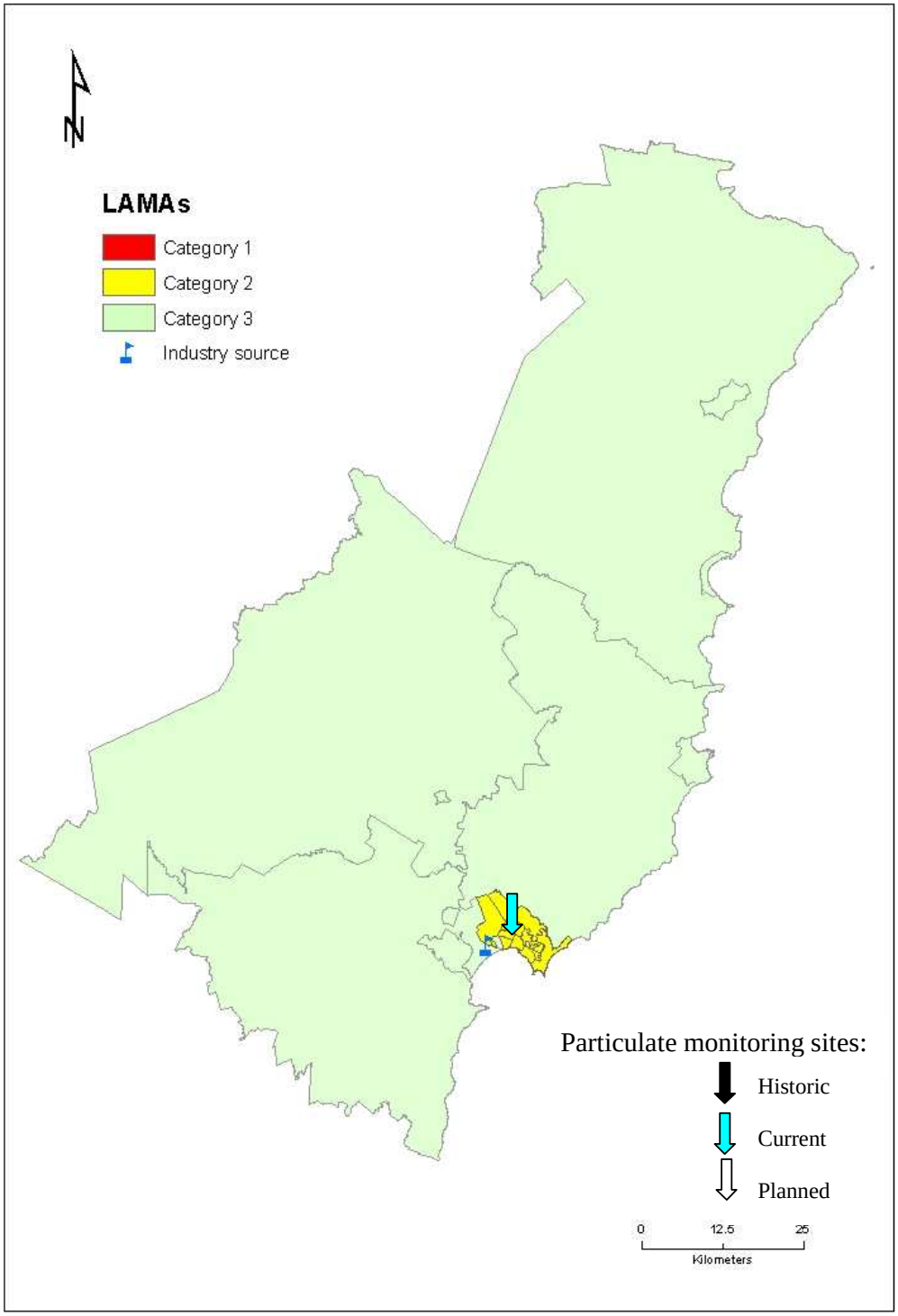


Figure 1.5 LAMA categories and Particulate Monitoring sites for the Gisborne Region.

In summary, the suggested LAMAs for the Gisborne District are:

Category 1 **None**

Category 2 Gisborne city central and environs
Category 2 Gisborne city south industrial zone

Category 3 All the rest

Thus there are 0 Category 1, 2 Category 2, and 1 Category 3 LAMAs

Table 1.5 provides a summary of past, current and planned $PM_{10}$ monitoring for the Gisborne Region.

Table 1.5 $PM_{10}$ monitoring undertaken in the Gisborne Region.

| Site | Lama Category | Dates of monitoring | Method of monitoring | Number of Exceedences recorded | Source of Information |
|---|---|---|---|---|---|
| Gisborne Oats Road | 2 | 93 to present | High Volume | 1 | MfE 2003 |

The information contained in Table 1.5 identifies:

- No

potential gaps in the Gisborne $PM_{10}$ monitoring network.

Sources of information

1) MfE 2003
*Monitoring of $PM_{10}$ in New Zealand*
http://www.mfe.govt.nz/publications/air

## 1.6 Hawke's Bay Region

Figure 1.6 shows the proposed LAMA categories and Particulate Monitoring sites for the Hawke's Bay Region.

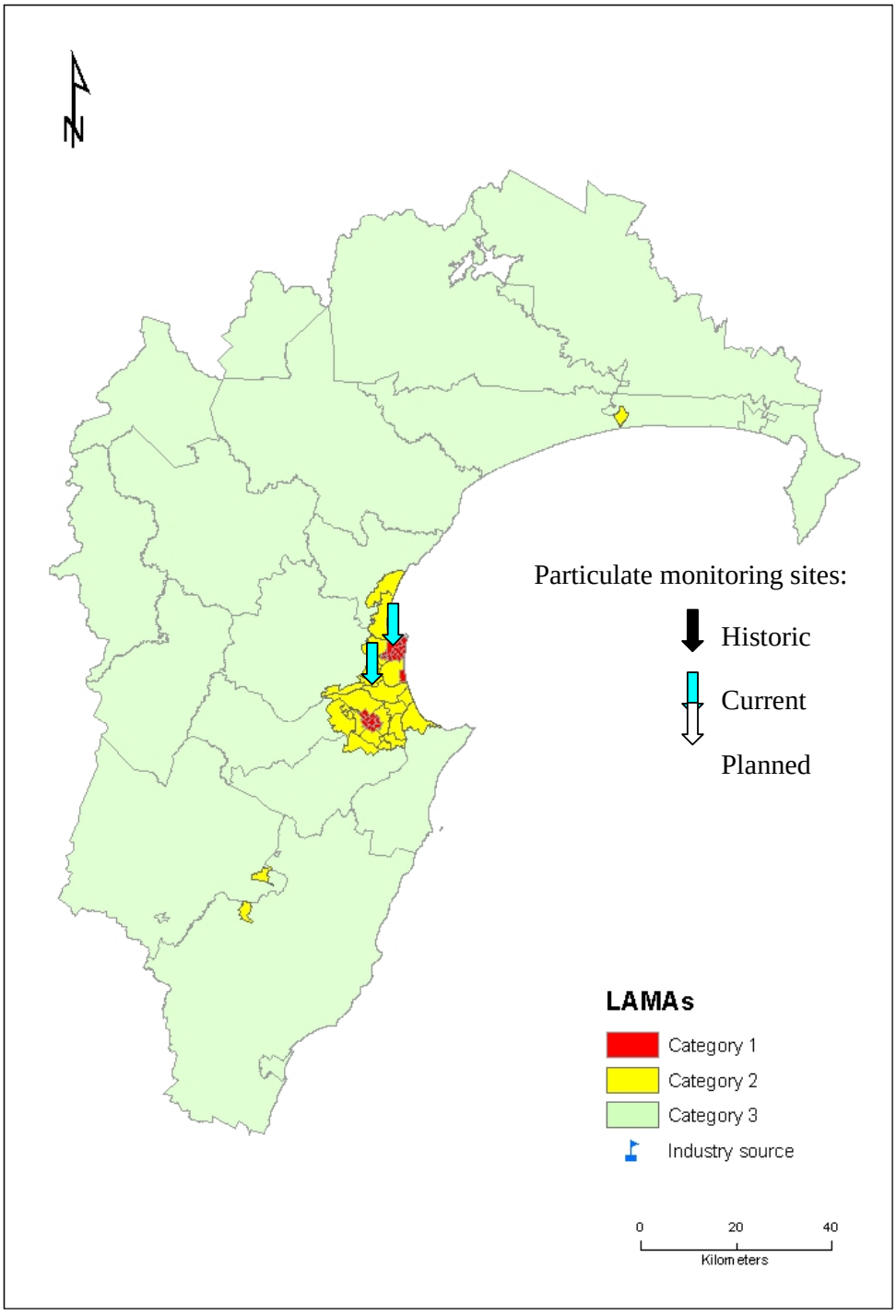


Figure 1.6 LAMA categories and Particulate Monitoring sites for the Hawke's Bay Region.

In summary, the suggested LAMAs for the Hawke's Bay Region are:

Category 1 **Napier**
Category 1 **Hastings**
Category 1 **Awatoto / Foreshore***
* Marginal due to small size and exposure

Other areas that may be considered for air quality management purposes are:

Category 2 Outer Napier through outer Hastings and Taradale to Whirinaki
Category 2 Wairoa
Category 2 Waipawa
Category 2 Waipukurau

Category 3 All the rest

Thus there are 3 Category 1, 4 Category 2, and 1 Category 3 LAMAs

Table 1.6 provides a summary of past, current and planned $PM_{10}$ monitoring for the Hawke's Bay Region.

Table 1.6 $PM_{10}$ monitoring undertaken in the Hawkes Bay Region.

| Site | Lama Category | Dates of monitoring | Method of monitoring | Number of Exceedences recorded | Source of Information |
|---|---|---|---|---|---|
| Napier (Guppy Road) | 1 | 98 to 99 | High Volume | 0 | MfE 2003<br>HBRC 2004 |
| Napier (Nelson Park) | 1 | 00 to 04 | High Volume | 2 | MfE 2003<br>HBRC 2004 |
| Hastings (St Johns College) | 1 | Aug 03 to Dec 04 | High Volume | 1 - 2003<br>7 - 2004 | HBRC 2004<br>HBRC 2005 |

The information contained in Table 1.6 identifies:

- **Awatoto / Foreshore**

Category 1 Lama as a potential gap in the Hawkes Bay $PM_{10}$ monitoring network.

*Sources of information*


*1) HBRC 2004*

*State of the Environment Air Quality 1998 to 2003*

*http://www.hbrc.govt.nz/Portals/57ad7180-c5e7-49f5-b282-c6475cdb7ee7/SOE_air04.pdf*

*2) MfE 2003*

*Monitoring of PM10 in New Zealand*

*http://www.mfe.govt.nz/publications/air/*

*3) HBRC, 2005*

*Air quality monitoring data provided by Hawke's Bay Regional Council staff - 2005*

## 1.7 Taranaki Region

Figure 1.7 shows the proposed LAMA categories and Particulate Monitoring sites for the Taranaki Region.

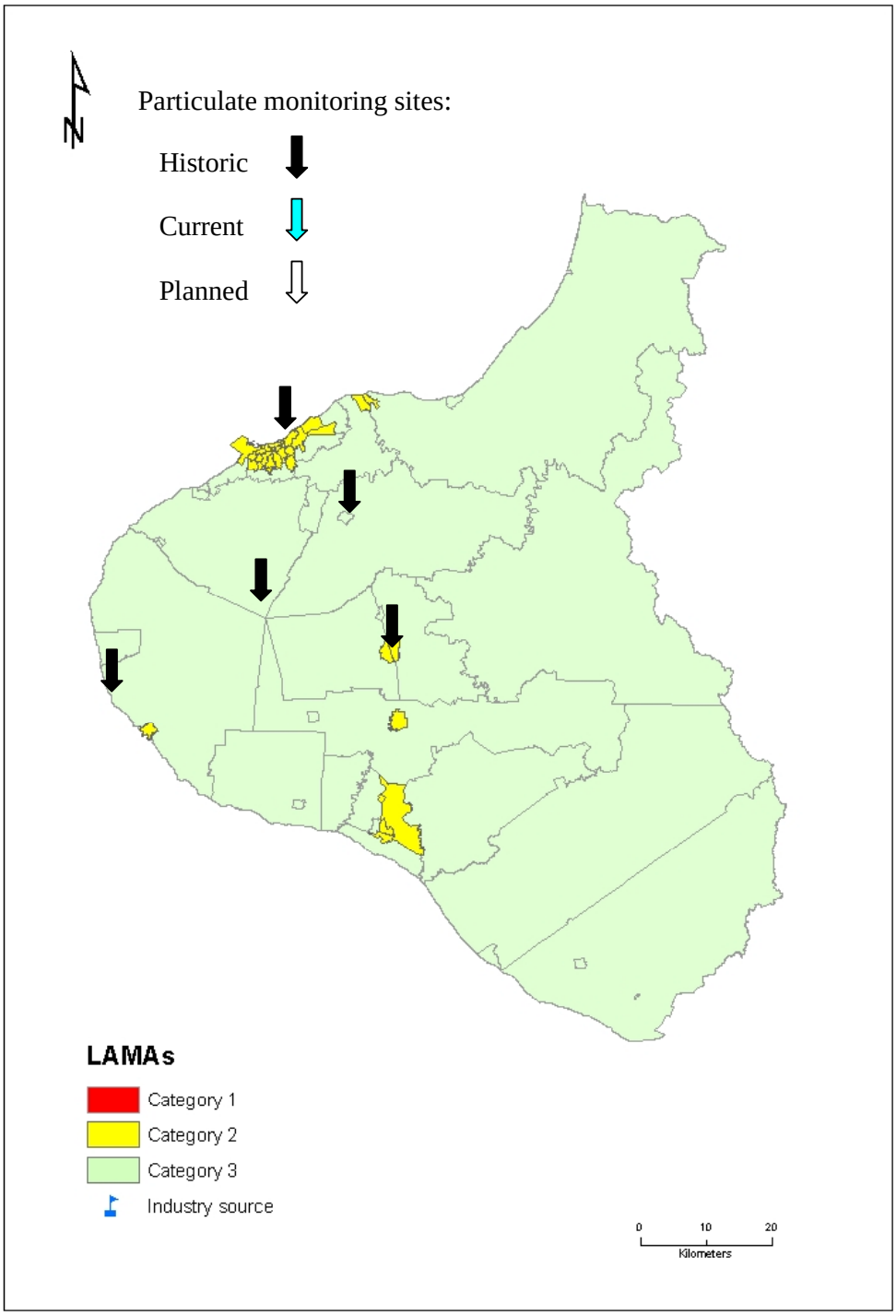


Figure 1.7 LAMA categories and Particulate Monitoring sites for the Taranaki Region.

In summary, the suggested LAMAs for the Taranaki Region are:

Category 1 **None at this stage**

Other areas that may be considered for air quality management purposes are:

Category 2 New Plymouth urban area
Category 2 Waitara
Category 2 Inglewood
Category 2 Stratford
Category 2 Eltham
Category 2 Normanby/ Hawerau
Category 2 Opunake

Category 3 All the rest

Thus there are 0 Category 1, 7 Category 2, and 1 Category 3 LAMAs

Table 1.7 provides a summary of past, current and planned $PM_{10}$ monitoring for the Taranaki Region.

Table 1.7 $PM_{10}$ monitoring undertaken in the Taranaki Region.

| Site | Lama Category | Dates of monitoring | Method of monitoring | Number of Exceedences recorded | Source of Information |
|---|---|---|---|---|---|
| Inglewood (rural) | 2 | Not stated | Not stated | 0 | TRC 2004 |
| Oaonui (Costal) | 3 | Not stated | Not stated | 0 | TRC 2004 |
| Stratford (semi-rural) | 2 | Not stated | Not stated | 0 | TRC 2004 |
| New Plymouth (urban) | 2 | May 03 to Oct 03 | High Volume | 0 | TRC 2004<br>TRC 2003 |
| Mt Taranaki (Pristine) | 3 | Not stated | Not stated | 0 | TRC 2004 |

The information contained in Table 1.7 identifies:

- No

potential gaps in the Taranaki $PM_{10}$ monitoring network.

*Sources of information*

*1) TRC 2004*
*Report on the State of the Environment of the Taranaki Region – 2003*
*http://www.trc.govt.nz/state_of_environment/index.html*
*2) TRC 2003*
*Inhaleable Particulate ($PM_{10}$) Regional Monitoring Programme Report 2003.*
*Technical Report 2003-99 ISSN 0114-8184*

## 1.8 Manawatu-Wanganui Region

Figure 1.8 shows the proposed LAMA categories and Particulate Monitoring sites for the Manawatu-Wanganui Region.

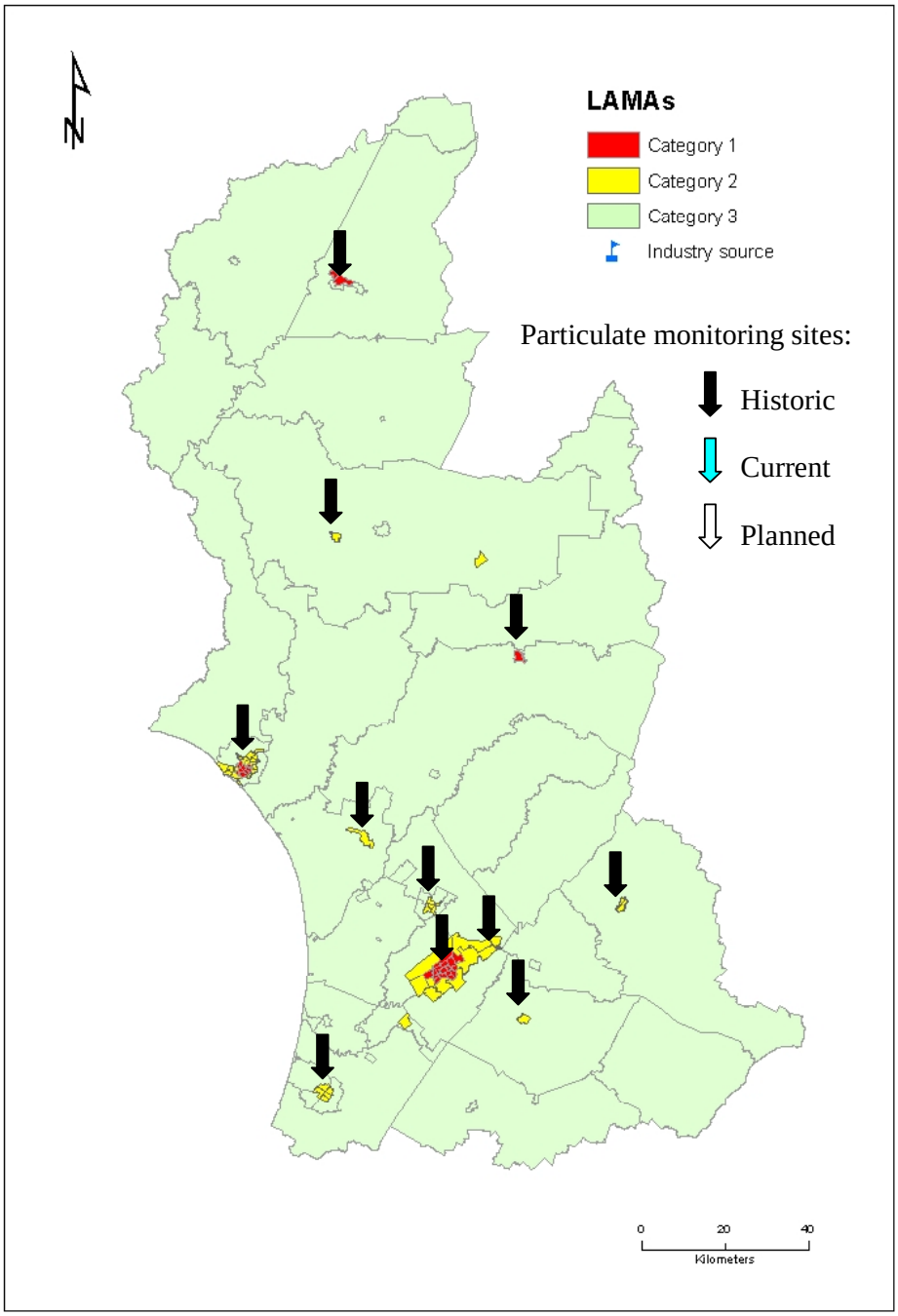


Figure 1.8 LAMA categories and Particulate Monitoring sites for the Manawatu-Wanganui Region.

In summary, the suggested LAMAs for the Wanganui / Manawatu Region are:

Category 1 **Palmerston North**
Category 1 **Wanganui**
Category 1 **Taumaranui**
Category 1 **Taihape**

Other areas that may be considered for air quality management purposes are:

Category 2 Outer Palmerston North / Fielding
Category 2 Outer Wanganui
Category 2 Ohakune
Category 2 Waiouru
Category 2 Levin
Category 2 Dannevirke
Category 2 Fielding
Category 2 Pahiatua
Category 2 Marton
Category 2 Ashhurst

Category 3 All the rest

Thus there are 4 Category 1, 10 Category 2, and 1 Category 3 LAMAs

Table 1.8 provides a summary of past, current and planned $PM_{10}$ monitoring for the Manawatu-Wanganui Region.

Table 1.8 $PM_{10}$ monitoring undertaken in the Manawatu-Wanganui Region.

| Site | Lama Category | Dates of monitoring | Method of monitoring (7-day average) | Number of Exceedences recorded | Source of Information |
|---|---|---|---|---|---|
| Taihape | 1 | May to Aug 2001 | Mini-vol | Exceedances recorded but frequency unknown | *Horizons.mw 2004 NIWA 2003* |
| Taumaranui | 1 | May to Aug 2001 | Mini-vol | Exceedances recorded but frequency unknown | |
| Wanganui | 1 | May to Aug 2001 | Mini-vol | Exceedence unlikely | |
| Palmerston North | 1 | May to Aug 2001 | Mini-vol | Exceedence unlikely | |
| Levin | 2 | May to Aug 2002 | Mini-vol | Exceedence unlikely | |
| Ashhurst | 2 | May to Aug 2002 | Mini-vol | Exceedence unlikely | |
| Dannevirke | 2 | May to Aug 2002 | Mini-vol | Exceedence unlikely | |
| Ohakune | 2 | May to Aug 2002 | Mini-vol | Potential Exceedence | |
| Martin | 2 | May to Aug 2003 | Mini-vol | Exceedence unlikely | |
| Fielding | 2 | May to Aug 2003 | Mini-vol | Potential Exceedence | |
| Pahiatua | 2 | May to Aug 2003 | Mini-vol | Potential Exceedence | |

The information contained in Table 1.8 identifies:

- **Taumaranui**
- **Taihape**
- **Ohakune**
- **Martin**
- **Pahiatua**
- **Palmerston North**
- **Wanganui**

Category 1 and 2 LAMAs as a potential gap in the Manawatu-Wanganui $PM_{10}$ monitoring network.

*Sources of information*


*1) Horizons.mw 2004*

*State of the Environment Report 2005: Chapter Seven - Air*

*http://www.horizons.govt.nz/default.asp?pageid=123*

*2) NIWA 2003*

*Horizons.mw Ambient Air Quality Monitoring $PM_{10}$, Winter 2003*

*NIWA report number AKL2003-154*

## 1.9 Wellington Region

Figure 1.9 shows the proposed LAMA categories and Particulate Monitoring sites for the Wellington Region.

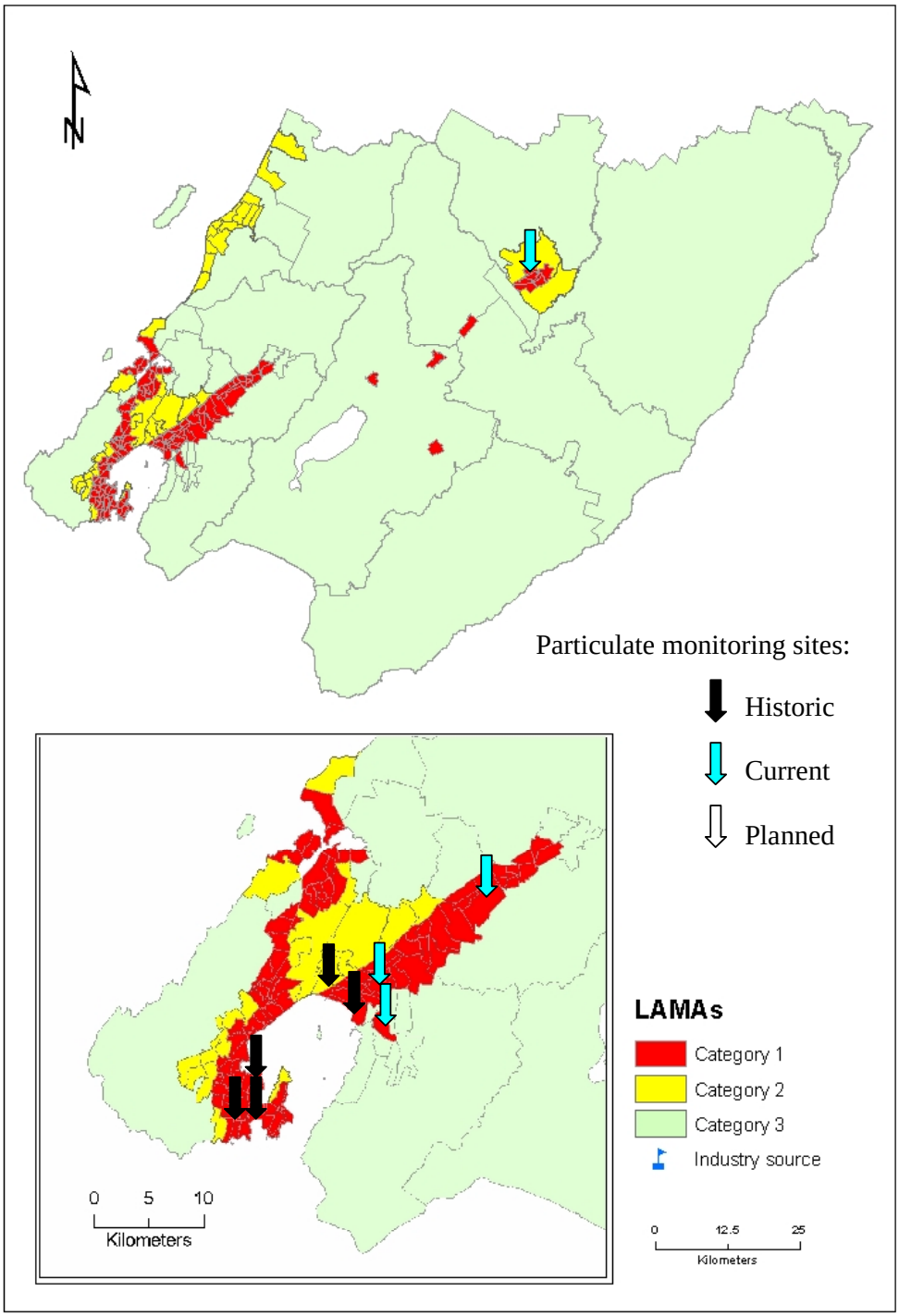


Figure 1.9 LAMA categories and Particulate Monitoring sites for the Wellington Region.

In summary, the suggested LAMAs for the Greater Wellington Region are:

Category 1 **Wellington City to Plimmerton**
Category 1 **Lower Hutt / Upper Hutt**
Category 1 **Wainuomata**
Category 1 **Masterton**
Category 1 **Carterton**
Category 1 **Greytown**
Category 1 **Featherstone**
Category 1 **Martinborough**

Other areas that may be considered for air quality management purposes are:

Category 2 Wellington northern suburbs
Category 2 Wellington western suburbs
Category 2 North Miramar peninsula
Category 2 Outer Masterton
Category 2 Titahi Bay
Category 2 Pukerua Bay
Category 2 Kapiti Coast – Paekakariki to Otaki

Category 3 All the rest

Thus there are 8 Category 1, 7 Category 2, and 1 Category 3 LAMAs

Table 1.9 provides a summary of past, current and planned $PM_{10}$ monitoring for the Wellington Region.

Table 1.9 $PM_{10}$ monitoring undertaken in the Wellington Region.

| Site | Lama Category | Dates of monitoring | Method of monitoring | Number of Exceedences recorded | Source of Information |
|---|---|---|---|---|---|
| Wellington (Civic Square) | 1 | Mar 98 to may 98 | TEOM | 0 | GWRC 1998 |
| Wellington (Govt House) | 1 | Mar 98 to Sep 98 | High Volume | 0 | GWRC 1998 |
| Wellington (Newton) | 1 | Mar 98 to Oct 98 | High Volume | 0 | MfE 2003 |
| Otaki | 2 | Oct 98 to Feb 00 | High Volume | 1 | MfE 2003 |
| Upper Hutt (Trentham Fire Station) | 1 | Oct 01 to Oct 03 | TEOM | 2 - 2000<br>4 - 2001<br>1 - 2002 | GWRC 2003<br>MfE 2003<br>MfE 2003 |
| Lower Hutt (Huia Pool) | 1 | May 98 to Sep 98 | TEOM | 0 | GWRC 1998 |
| Lower Hutt Mabey Road | 1 | Oct 97 to Mar 98 | TEOM | 0 | GWRC 1998 |
| Lower Hutt (Birch Lane) | 1 | Oct 01 to Oct 03 | TEOM | 0 | GWRC 2003 |
| Wainuiomata | 1 | Sep 00 to Nov 03 | High Volume | 6 | GWRC 2003 |
| Masterton (Memorial Park) | 1 | 1999 | Hi Volume | 8 | MfE 2003 |
| Masterton (Wairarapa College) | 1 | Oct 02 to Oct 03 | TEOM and High-Volume | 5 Approx | GWRC 2003 |

The information contained in Table 1.9 identifies:

- **Johnsonville, Porirua and Plimmerton**
- **Carterton**
- **Greytown**
- **Featherstone**
- **Martinborough**

Category 1 LAMAs as potential gaps in the Wellington $PM_{10}$ monitoring network.

*Sources of information*


*1) GWRC 2003*

*2003 Annual Air Quality Monitoring Report for the Wellington Region*

*http://www.gw.govt.nz/council-publications/pdfs/Environment%20Management_20040122_160815.pdf*

*2) MfE 2003*

*Monitoring of PM10 in New Zealand*

*http://www.mfe.govt.nz/publications/air/*

*3) GWRC 2002*

*2002 Annual Air Quality Monitoring Report for the Wellington Region*

*http://www.gw.govt.nz/council-publications/pdfs/Environment%20Management_20030312_091913.pdf*

*4) GWRC 2001*

*Petone-Seaview Ambient Air Quality Monitoring Strategy*

*http://www.gw.govt.nz/council-publications/pdfs/Environment%20Management_200110262_101503.pdf*

*5) GWRC 2000*

*Wellington Regional Council Air Quality Monitoring Strategy 2000-2005*

*Publication Number WRC/RINV-T-00/20*

*6) GWRC 1998*

*Annual Air Quality Monitoring Report 1998*

*Publication Number WRC/RINV-T-98/58*

## 1.10 Marlborough Region

Figure 1.10 shows the proposed LAMA categories and Particulate Monitoring sites for the Marlborough Region.

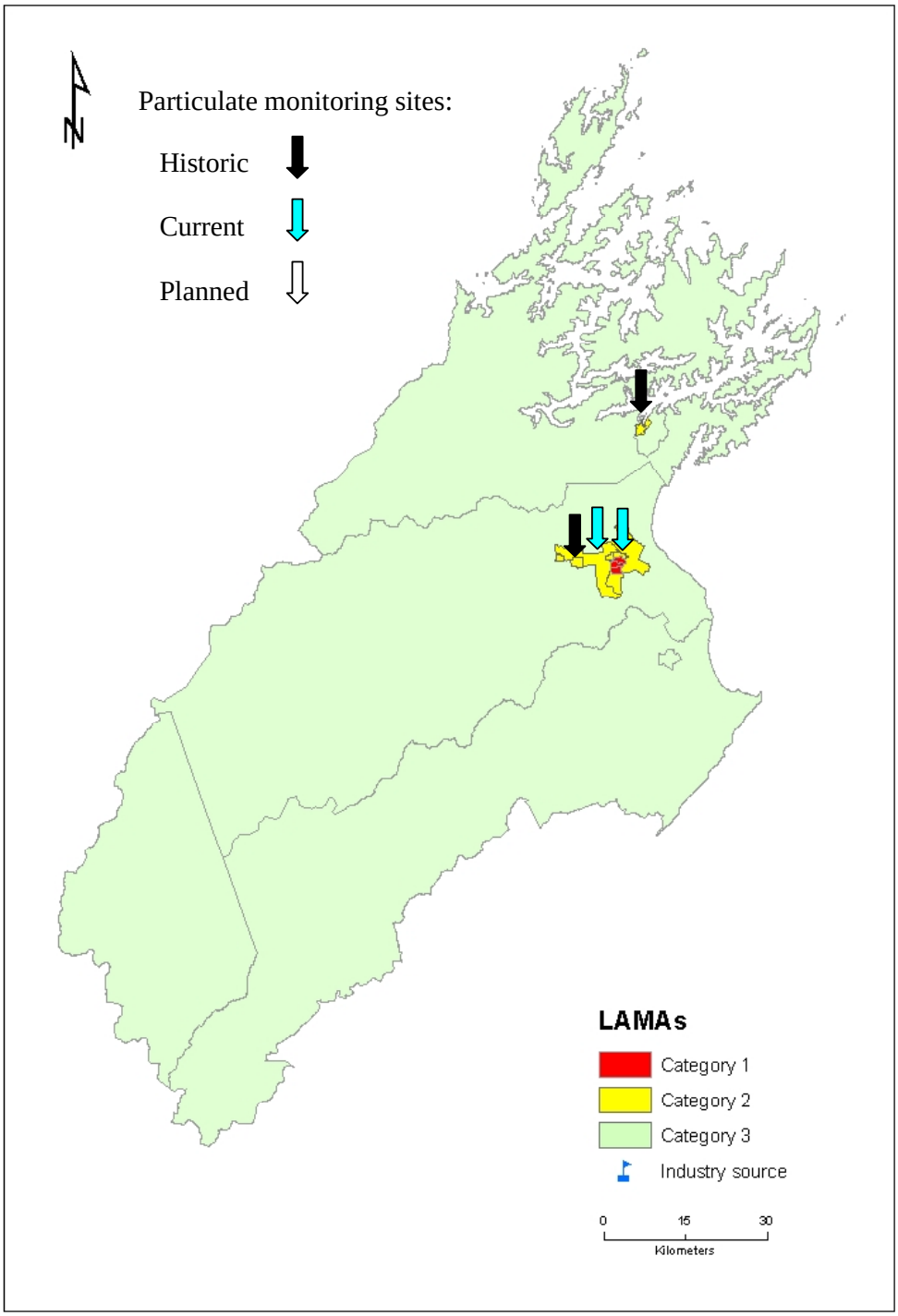


Figure 1.10 LAMA categories and Particulate Monitoring sites for the Marlborough Region.

In summary, the suggested LAMAs for Marlborough are:

Category 1 **Blenheim**

Other areas that may be considered for air quality management purposes are:

Category 2 Outer Blenheim
Category 2 Picton

Category 3 All the rest

Thus there are 1 Category 1, 2 Category 2, and 1 Category 3 LAMAs

Table 1.10 provides a summary of past, current and planned $PM_{10}$ monitoring for the Marlborough Region.

Table 1.10 $PM_{10}$ monitoring undertaken in the Marlborough Region.

| Site | Lama Category | Dates of monitoring | Method of monitoring | Number of Exceedences recorded | Source of Information |
|---|---|---|---|---|---|
| Blenheim (Middle Renwick Road) | 1 | Feb 00 to Dec 03 | High Volume | 1-2000<br>0-2001<br>0-2002<br>1-2003 | MDC 2002<br>MDC 2003<br>MDC 2004 |
| Blenheim (Redwoodtown) | 1 | Sep 01 to Dec 01<br>May 02 to Sep 02 | High Volume | 0-2001<br>5-2002<br>7-2003 | MDC 2002<br>MDC 2003<br>MDC 2004 |
| Renwick | 2 | May 02 to Aug 02 | High Volume | 0-2002 | MDC 2003 |
| Picton | 2 | Oct 02 – Sep 03 | High Volume | 0-2002<br>0-2003 | MDC 2003<br>MDC 2004 |

The information contained in Table 1.10 identifies:

- No

potential gaps in the Marlborough $PM_{10}$ monitoring network.

*Sources of information*


*1) MDC 2004a*
*Ambient Air Quality Monitoring Report - 2003*
*http://www.marlborough.govt.nz/enviromonitoring/air.cfm*
*2) MDC 2004b*
*State of the Environment Report 2003/2004 - Air*
*http://www.marlborough.govt.nz/enviromonitoring/sote.cfm*
*3) MDC 2003*
*Ambient Air Quality Monitoring Report - 2002*
*http://www.marlborough.govt.nz/enviromonitoring/air.cfm*
*4) MDC 2002*
*Ambient Air Quality Monitoring Report - 2001*
*http://www.marlborough.govt.nz/enviromonitoring/air.cfm*

## 1.11 Nelson Region

Figure 1.11 shows the proposed LAMA categories and Particulate Monitoring sites for the Nelson Region.

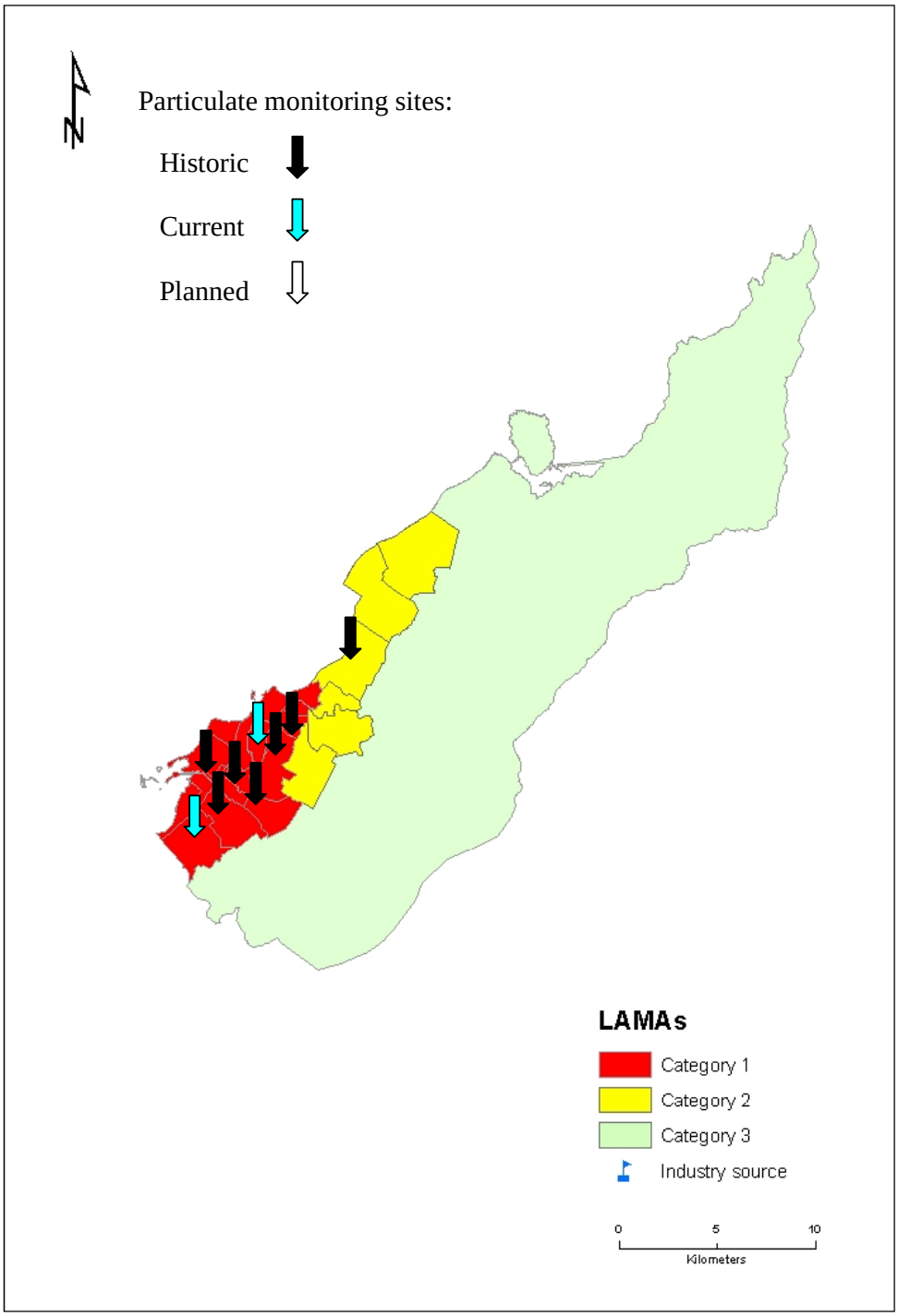


Figure 1.11 LAMA categories and Particulate Monitoring sites for the Nelson Region.

In summary, the suggested LAMAs for Nelson are:

Category 1 **Nelson / Port / Tahunanui***
* These may be optimally split into finer scale separate airsheds for management purposes.

Other areas that may be considered for air quality management purposes are:

Category 2 North Nelson

Category 3 All the rest

Thus there are 1 Category 1, 1 Category 2, and 1 Category 3 LAMAs

Table 1.11 provides a summary of past, current and planned $PM_{10}$ monitoring for the Marlborough Region.

Table 1.11 $PM_{10}$ monitoring undertaken in the Nelson Region.

| Site | Lama Category | Dates of monitoring | Method of monitoring | Number of Exceedences recorded | Source of Information |
|---|---|---|---|---|---|
| Nelson (St Vincent St) | 1 | Apr 01 to Oct 04 | Partisol | 81-2001<br>59-2002<br>68-2003<br>65-2004 | NCC 2001<br>NIWA 2002b<br>NIWA 2003<br>NCC 2004 |
| Nelson (Victory School) | 1 | Apr 01 to Sep 01 | Partisol | 34-2001*<br>32-2002<br>55-2003 | NIWA 2001<br>NIWA 2002b<br>NIWA 2003 |
| Nelson (Hospital) | 1 | Apr 01 to Sep 01<br>Dec 01 to Jan 02 | TEOM | 12-2001 | NIWA 2001<br>NIWA 2002a |
| Nelson (The Wood) | 1 | May 03 to Jun 03 | Partisol | 0 | NIWA 2003 |
| Nelson (The Brook) | 1 | July 03 | Partisol | 1-2003 | NIWA 2003 |
| Stoke (Keats Cresent) | 1 | Aug 03 | Partisol | 1-2003 | NIWA 2003 |
| Stoke (Nayland Road) | 1 | Apr 04 to Sept 04 | Partisol | 27-2004 | NCC 2004 |
| Tahunanui (Roto Street) | 1 | Aug 04 to Oct 04 | Partisol | 1-2004 | NCC 2004 |
| Dodson Valley | 2 | Jun 04 to Aug 04 | Partisol | 0-2004 | NCC 2004 |

*estimated based on 10 measured exceedences.

The information contained in Table 1.11 identifies:

- No

potential gaps in the Nelson $PM_{10}$ monitoring network.

*Sources of information*


*1) NCC 2004*

*Nelson City Council PM10 Air Quality Monitoring Data -2004*

*2) NIWA 2003*

*Report AKL2003-150. Bluett J. and Gray S. 2003. Ambient air monitoring Nelson City: winter 2003. pp 55.*

*3) NIWA 2002a*

*NIWA Report AK02048. Bluett, J. and Petersen J. 2002. Ambient air monitoring Nelson City December 2001 – January 2002. pp 53.*

*4) NIWA 2002b*

*Report AKL2002-066. Fisher G. and Gray S. 2002. Ambient air monitoring Nelson City: winter 2002. pp 53.*

*5) NCC 2001*

*Nelson State of the Environment Report: The Air and Noise Report - 2001*

*http://www.nelsoncitycouncil.co.nz/environment/SOE/SOE_01/air_quality_&_transport_noise.htm*

*6) NIWA 2001*

*Report AK01135. Bluett, J. and Petersen J. 2001. Ambient air monitoring Nelson City autumn winter 2001. pp 82.*

## 1.12 Tasman Region

Figure 1.12 shows the proposed LAMA categories and Particulate Monitoring sites for the Tasman Region.

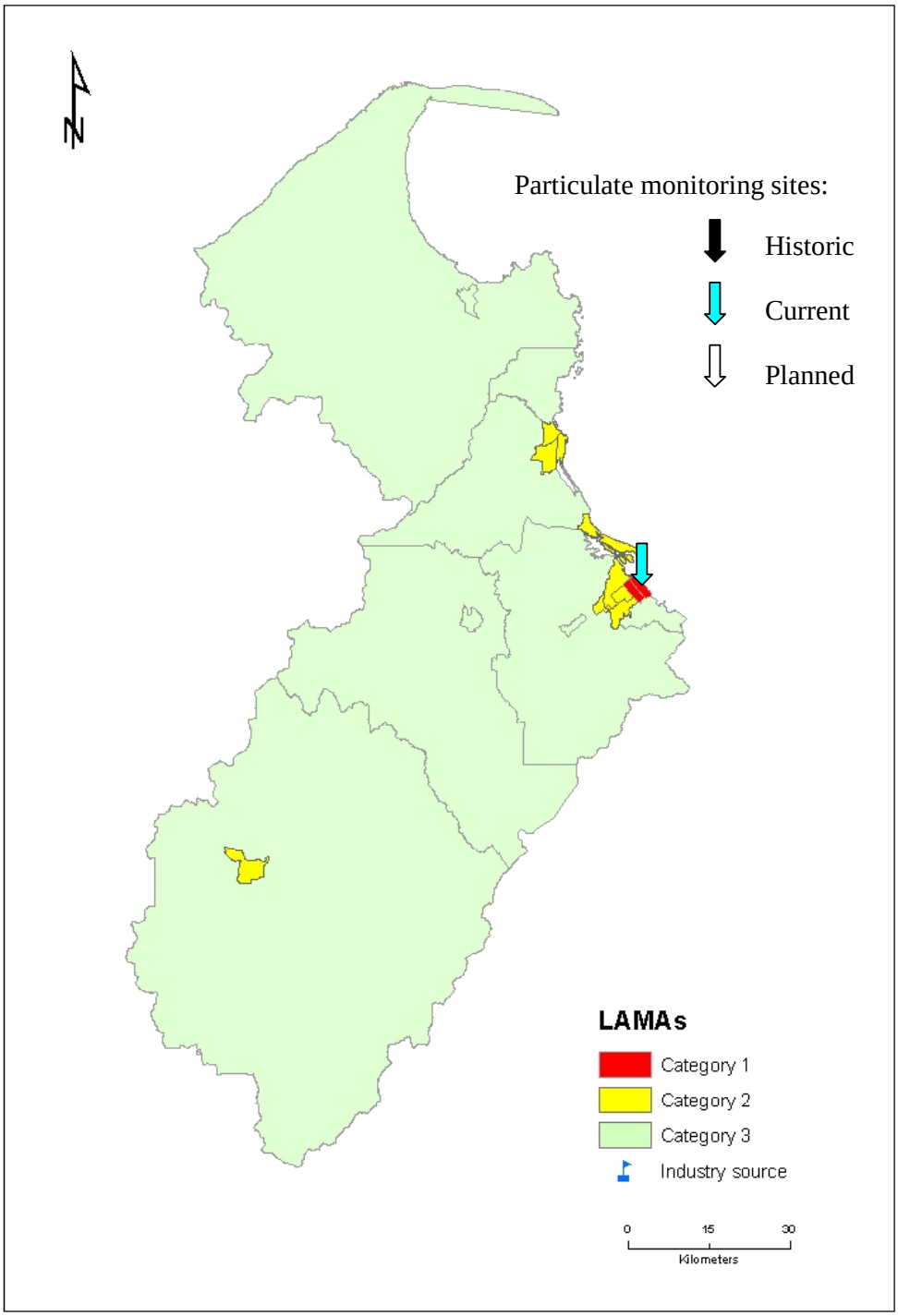


Figure 1.12 LAMA categories and Particulate Monitoring sites for the Tasman Region.

In summary, the suggested LAMAs for Tasman District are:

Category 1 **Richmond**

Other areas that may be considered for air quality management purposes are:

Category 2 Outer Richmond to Ruby Bay
Category 2 Motueka
Category 2 Murchison

Category 3 All the rest

Thus there are 1 Category 1, 3 Category 2, and 1 Category 3 LAMAs

Table 1.12 provides a summary of past, current and planned $PM_{10}$ monitoring for the Tasman Region.

Table 1.12 $PM_{10}$ monitoring undertaken in the Tasman Region.

| Site | Lama Category | Dates of monitoring | Method of monitoring | Number of Exceedences recorded | Source of Information |
|---|---|---|---|---|---|
| Richmond | 1 | May to Sept 2000<br>Aug to Dec 2002<br>2003 to 2004 | High Volume | 23- 2000*<br>5 - 2002<br>40-2003<br>38-2004 | MfE 2003*<br>TDC 2002<br>TDC 2005 |

The information contained in Table 1.12 identifies:

- No

potential gaps in the Tasman $PM_{10}$ monitoring network.

*Sources of information*


*1) TDC 2004*

*Resource Management Policy Committee Newsbriefs - November 2004*

*http://www.tdc.govt.nz/story.asp?id=1521*

*2) MfE 2003*

*Monitoring of $PM_{10}$ in New Zealand*

*http://www.mfe.govt.nz/publications/air/*

*3) TDC 2002*

*Environment Today Tasman 2000. Air Resources*

*http://www.tdc.govt.nz/environmenttasman.asp?page=Environment+Tasman&story=501*

*4) TDC, 2005*

*Air quality monitoring data supplied by Tasman District Council staff*

## 1.13 Canterbury Region

Figure 1.13 shows the proposed LAMA categories and Particulate Monitoring sites for the Canterbury Region.

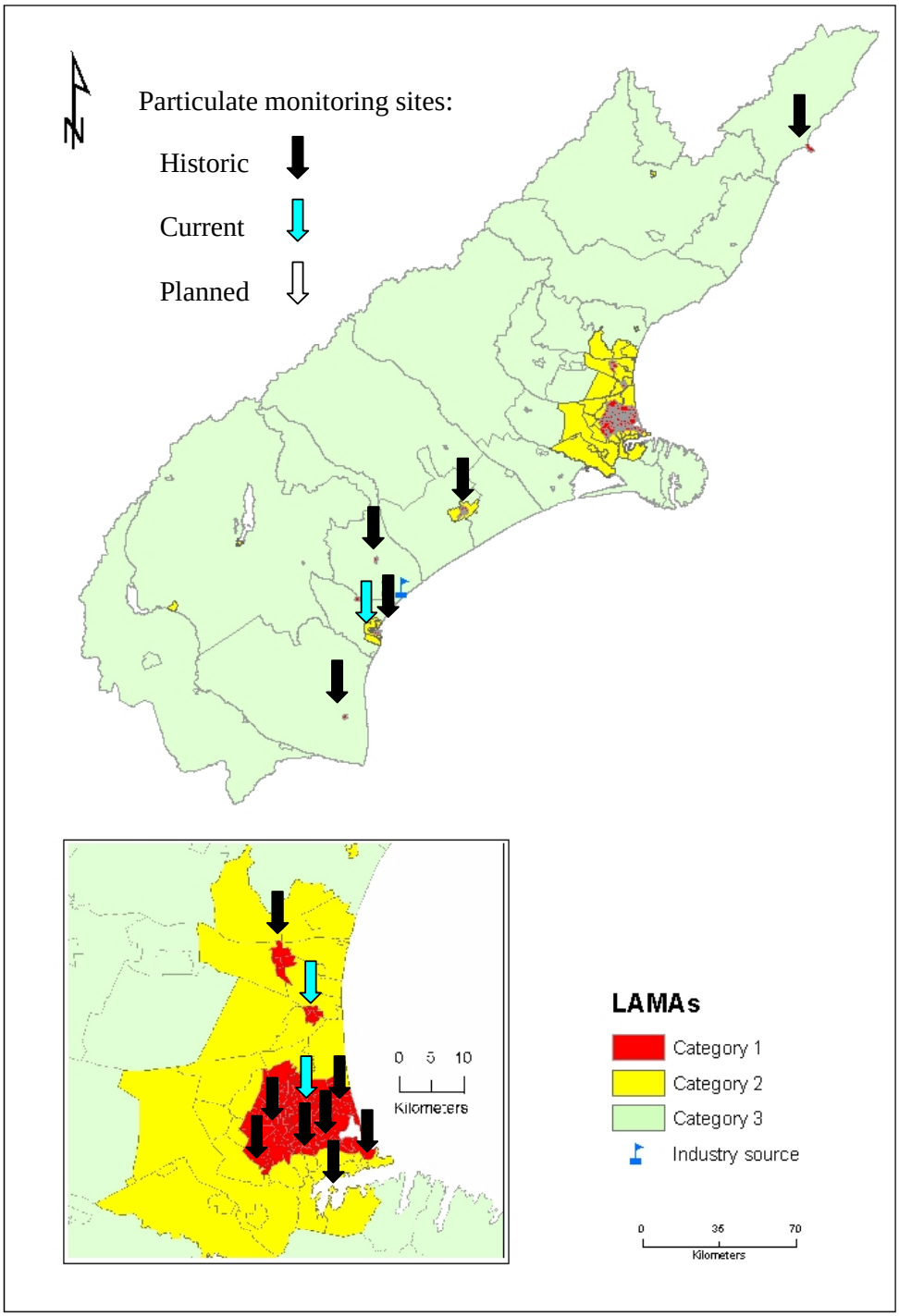


Figure 1.10 LAMA categories and Particulate Monitoring sites for the Canterbury Region.

In summary, the suggested LAMAs for the Canterbury Region are:

Category 1 **Christchurch City**
Category 1 **Belfast**
Category 1 **Kaiapoi**
Category 1 **Rangiora**
Category 1 **Ashburton**
Category 1 **Timaru**
Category 1 **Waimate**
Category 1 **Ashburton**
Category 1 **Kaikoura**

Other areas that may be considered for air quality management purposes are:

Category 2 Outer Christchurch – from Woodend to Lincoln (perhaps further)
Category 2 Outer Ashburton
Category 2 Outer Timaru
Category 2 Amberley
Category 2 Hamner Springs
Category 2 Lyttleton
Category 2 Fairlie
Category 2 Geraldine
Category 2 Tekapo
Category 2 Twizel

Category 3 All the rest

Thus there are 8 Category 1, 10 Category 2 and 1 Category 3 LAMAs

Table 1.13 provides a summary of past, current and planned $PM_{10}$ monitoring for the Canterbury Region.

Table 1.13 $PM_{10}$ monitoring undertaken in the Canterbury Region.

| Site | Lama Category | Dates of monitoring | Method of monitoring | Number of Exceedences recorded | Source of Information |
|---|---|---|---|---|---|
| Christchurch: St Albans-Coles Place | 1 | Aug 1998 to 2003 | TEOM | 2-1998<br>31-1999<br>21-2000<br>39-2001<br>17-2002<br>23-2003 | ECAN 2004 |
| Christchurch: St Albans-Coles Place) | 1 | Aug 1998 to 2003 | High Volume | 5-2001<br>25-2002<br>29-2003 | ECAN 2004 |
| Christchurch: Aranui | 1 | Jun 02 Jan 04 | TEOM | 9-2002<br>17-2003 | ECAN 2004 |
| Christchurch: Hoon Hay | 1 | Feb 02 to Mar 04 | TEOM | 10-2002<br>9-2003 | ECAN 2004 |
| Christchurch: Hornby | 1 | Jun 95 to Dec 98 | TEOM | 3-1995<br>2-1996<br>13-1997<br>13-1998 | ECAN 2004 |
| Christchurch: Beckenham | 1 | Jun 95 to Mar 97 | TEOM | 2-1995<br>8-1996<br>0-1997 | ECAN 2004 |

| Site | Lama Category | Dates of monitoring | Method of monitoring | Number of Exceedences recorded | Source of Information |
|---|---|---|---|---|---|
| Christchurch: Opawa | 1 | Jun 95 to Jan 96<br>Jul 96 to Jun 99 | TEOM | 28-1995<br>23-1996<br>22-1997<br>21-1998<br>13-1999 | ECAN 2004 |
| Christchurch: Sumner | 1 | Jul 99 to Aug 99<br>Aug 99 to Jan 00<br>Jul 01 to Feb 02 | TEOM | 0-1999<br>33-2000<br>23-2001<br>3-2002 | ECAN 2004 |
| Christchurch: St Albans-Packe Street | 1 | May 88 to 2002 | Beta Gauge | 31-1988<br>35-1989<br>26-1990<br>27-1991<br>39-1992<br>23-1993<br>2-1994<br>34-1996<br>45-1997<br>30-1998<br>43-1999<br>36-2000<br>0-2001<br>9-2002 | ECAN 2004 |
| Christchurch: St Albans-Packe Street | 1 | 1994 and 1996 | High Volume | 12-1994<br>10-1996 | ECAN 2004 |
| Christchurch: St Albans-Packe Street | 1 | May 94 to 2002 | TEOM | 5-1994<br>31-1995<br>28-1996<br>27-1997<br>27-1998<br>27-1999<br>9-2000<br>13-2001 | ECAN 2004 |
| Kaikoura | 1 | Mar 02 to Feb 03 | TEOM | 21-2002 | ECAN 2004 |
| Rangiora | 1 | Dec 98 to Feb 01 | TEOM | 4-1999<br>3-2000 | ECAN 2004 |
| Kaiapoi | 1 | Mar 01 to 03 | TEOM | 25-2001<br>15-2002<br>21-2003 | ECAN 2004 |
| Lyttelton (4 sites) | 2 | Jun 03 | Mini Vol | 0 | ECAN 2004 |
| Ashburton | 1 | Jan 98 to Mar 01 | TEOM | 5-1999<br>4-2000<br>0-2001 | ECAN 2004 |
| Geraldine | 2 | Mar 03 to Dec 04 | TEOM | 0 | ECAN 2004 |
| Timaru: Washdyke | 2 | Apr 01 to Mar 02 | TEOM | 2-2001 | ECAN 2004 |
| Timaru | 1 | Jan 97 to 03 | TEOM | 21-1997<br>27-1998<br>32-1999<br>31-2000<br>29-2001<br>19-2002<br>35-2003 | ECAN 2004 |
| Waimate | 1 | Mar 02 to Dec 03 | TEOM | 0-2002<br>1-2003 | ECAN 2004 |

The information contained in Table 1.13 identifies:

- **Belfast**
- **Rangiora**
- **Ashburton**
- **Waimate**
- **Ashburton**
- **Kaikoura**

Category 1 LAMAs as potential gaps in the Canterbury $PM_{10}$ monitoring network.

*Sources of information*

*1) ECAN 2004*

*Annual Ambient Air Quality Monitoring Report – 2003*

*http://www.ecan.govt.nz/Plans+and+Reports/Air/Annual+Monitoring+Report/default.htm*

*2) ECAN 2003*

*Annual Ambient Air Quality Monitoring Report – 2002*

*http://www.ecan.govt.nz/Plans+and+Reports/Air/Annual+Monitoring+Report/default.htm*

## 1.14 West Coast Region

Figure 1.14 shows the proposed LAMA categories and Particulate Monitoring sites for the West Coast Region.

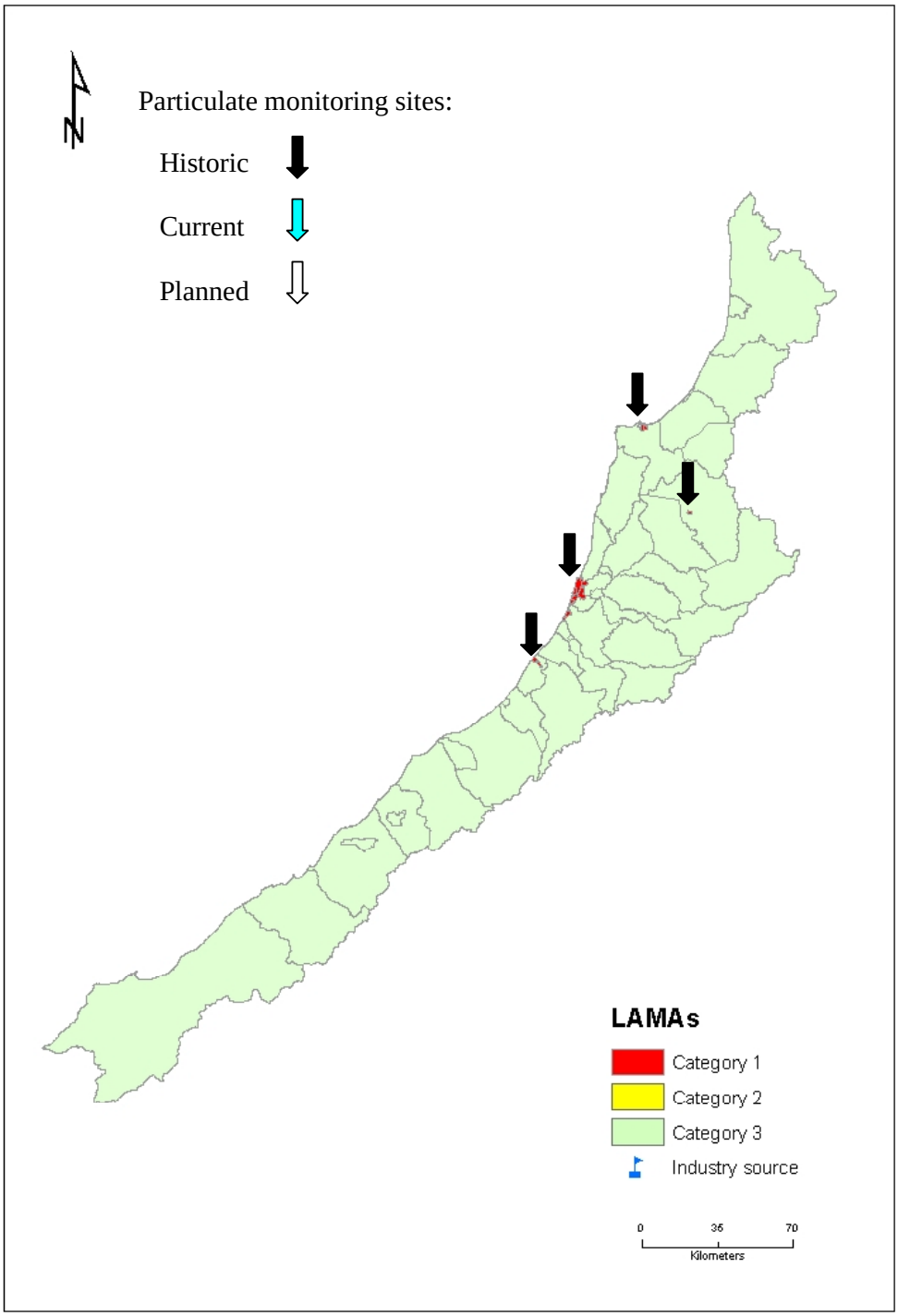


Figure 1.14 LAMA categories and Particulate Monitoring sites for the West Coast Region.

In summary, the suggested LAMAs for the West Coast Region are:

Category 1 **Westport**
Category 1 **Greymouth**
Category 1 **Hokitika**
Category 1 **Reefton***
* Optional due to the small size of this centre

Other areas that may be considered for air quality management purposes are:

Category 2 None

Category 3 All the rest

Thus there are 4 Category 1, 0 Category 2, and 1 Category 3 LAMAs

Table 1.14 provides a summary of past, current and planned $PM_{10}$ monitoring for the West Coast Region.

Table 1.14 $PM_{10}$ monitoring undertaken in the West Coast Region.

| Site | Lama Category | Dates of monitoring | Method of monitoring | Number of Exceedences recorded | Source of Information |
|---|---|---|---|---|---|
| Greymouth (Palmerston Street) | 1 | May 01 to Aug 01<br>Feb 04 to Mar 04 | High Volume | 0 | WCRC 2004 |
| Westport (Derby Street) | 1 | May 02 to Aug 02 | High Volume | 3 | WCRC 2004 |
| Reefton | 1 | May 03 to Sep 03 | High Volume | 4 | WCRC 2004 |
| Hokitika | 1 | Nov 02 to Feb 03 | TEOM | 0 | WCRC 2004 |

The information contained in Table 1.14 identifies:

- **Westport**
- **Greymouth**
- **Hokitika**
- **Reefton**

Category 1 LAMAs as potential gaps in the West Coast $PM_{10}$ monitoring network.

*Sources of information*

*1) WCRC 2004*
*State of the Environment Report: West Coast Ambient Air Quality*
*http://www.wcrc.govt.nz/aspcommon/layout1/*

## 1.15 Otago Region

Figure 1.15 shows the proposed LAMA categories and Particulate Monitoring sites for the Otago Region.

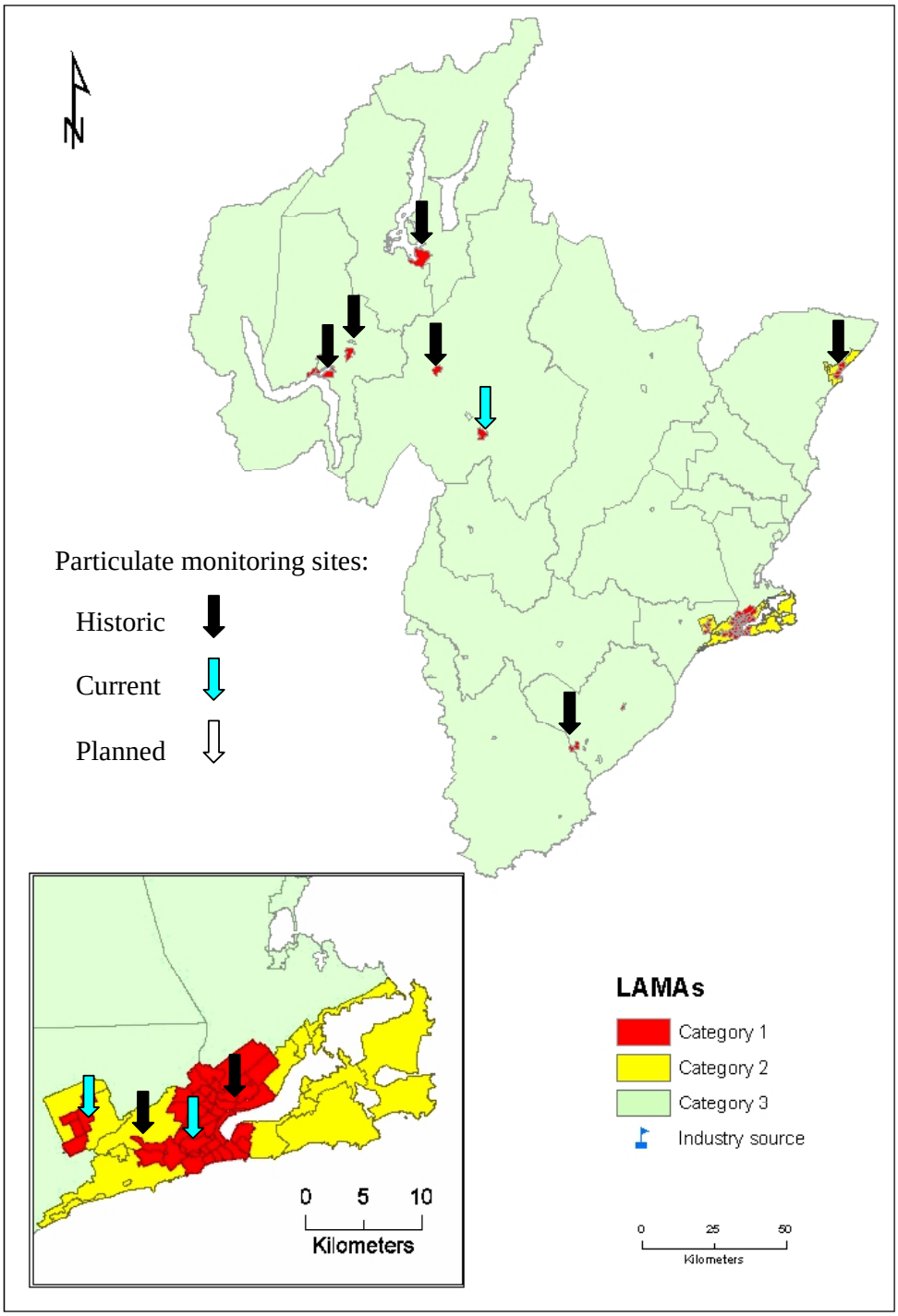


Figure 1.15 LAMA categories and Particulate Monitoring sites for the Otago Region.

In summary, the suggested LAMAs for the Otago Region are:

Category 1 **Dunedin**
Category 1 **Mosgiel**
Category 1 **Balclutha**
Category 1 **Oamaru**
Category 1 **Wanaka**
Category 1 **Arrowtown**
Category 1 **Queenstown**
Category 1 **Cromwell**
Category 1 **Alexandra**
Category 1 **Milton**
Category 1 **Palmerston**
Category 1 **Clyde***
*Optional due to small size of the area

Other areas that may be considered for air quality management purposes are:

Category 2 Greater Dunedin/Mosgiel / Otago Peninsula
Category 2 Outer Oamaru
Category 3 All the rest

Thus there are 10 Category 1, 2 Category 2, and 1 Category 3 LAMAs

Table 1.15 provides a summary of past, current and planned $PM_{10}$ monitoring for the Otago Region.

Table 1.15 $PM_{10}$ monitoring undertaken in the Otago Region.

| Site | Lama Category | Dates of monitoring | Method of monitoring | Number of Exceedences recorded | Source of Information |
|---|---|---|---|---|---|
| Alexandra | 1 | Apr 97 to Sep 98 | Mini Volume | 12-1997 | MfE 2003 |
| Alexandra | 1 | Jun 97 to Aug 02 | High Volume | 8-1998<br>9-1999<br>9-2000<br>9-2001 | ORC 2002<br>MfE 2003 |
| Alexandra | 1 | Jun 02 to Sep 02 | TEOM | 19 | NIWA 2003 |
| Alexandra | 1 | Jan 03 to Dec 04 | High Volume | 17 – 2003<br>26 - 2003 | ORC, 2004 |
| Oamaru | 1 | Jun 98 to Aug | Mini Vol | 1 | MfE 2003 |
| Cromwell | 1 | Jun 99 to Aug 99<br>Jun 01 to Aug 01<br>Jun to Aug 04 | Mini Vol | 5-1999<br>5 - 2004 | MfE 2003<br>ORC, 2004 |
| Mosgiel | 1 | Jun 98<br>Jun 00 to Sep 01 | Mini Vol | 5-1998<br>1-2000<br>2-2001 | MfE 2003 |
| Mosgiel | 1 | Jun 01 onward | High Volume | 3 – 2002<br>4 – 2003<br>11 - 2004 | ORC, 2004 |
| Milton | 1 | Jun 99 to Sep 99 | Mini Vol | 2 | MfE 2003 |
| Clyde | 1 | Jun to Sept 02 | Mini Vol | 0 | ORC, 2004 |
| Balclutha | 1 | Jun 97 to Sep 97<br>Jun 00 to Sep 00 | Mini Vol | 1-1997 | MfE 2003 |
| Arrowtown | 1 | Jul 99 to Sep 99<br>Jun to Aug 03<br>Jun to Aug 04 | Mini Vol | 1 – 99<br>4 – 2003<br>4 - 2004 | MfE 2003<br>ORC, 2004 |
| Queenstown | 1 | Jun 99 to Aug 99 | Mini Vol | 0 | MfE 2003 |
| Wanaka | 1 | Jun to Aug 03 | Mini Vol | 0 | ORC, 2004 |
| Palmerston | 1 | Jun to Aug 03 | Mini Vol | 4 | ORC, 2004 |
| Dunedin | 1 | Jun 97 to Sep 97 | Mini Vol | 2-1997 | MfE 2003, |

| | | | | | |
|---|---|---|---|---|---|
| (Green Island) | | Jun 00 to Aug 00<br>Jul 01 to Aug 01<br>Jun to Sept 02 | | 2-2000<br>1-2001<br>5 - 2002 | ORC, 2004 |
| Dunedin (N East Valley) | 1 | 02-04 | Hi-vol | 0 | ORC, 2004 |
| Dunedin (South) | 1 | Jun to Sept 02 | Mini Vol | 2 | ORC, 2004 |

The information contained in Table 1.15 identifies:

- **Balclutha**
- **Oamaru**
- **Wanaka**
- **Arrowtown**
- **Queenstown**
- **Milton**
- **Palmerston**
- **Clyde**

Category 1 LAMAs as potential gaps in the Otago $PM_{10}$ monitoring network.

*Sources of information*


*1) MfE 2003*

*Monitoring of $PM_{10}$ in New Zealand*

*http://www.mfe.govt.nz/publications/air/*

*2) NIWA 2003*

*Report AKL2003-065. Bluett J., Gray S. and Reddish L. 2003. Otago Regional Council Ambient Air Quality Monitoring, Winter 2002. pp 27.*

*3) ORC 2002*

*Alexandra Air Quality*

*http://www.orc.govt.nz/html/details.html?ArticleID=214*

*4) ORC, 2004*

*Air quality monitoring data provided by ORC staff*

## 1.16 Southland Region

Figure 1.16 shows the proposed LAMA categories and Particulate Monitoring sites for the Southland Region.

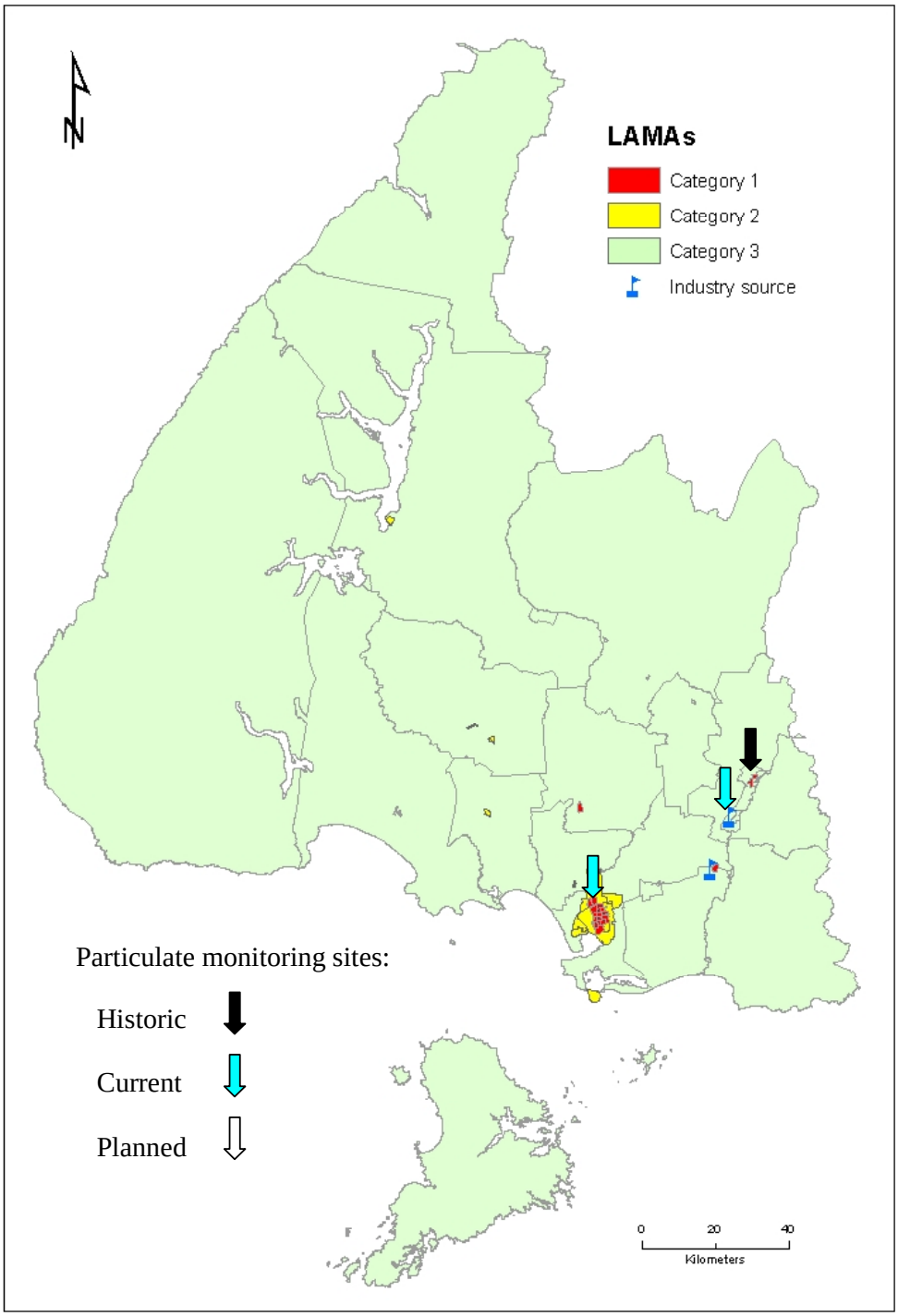


Figure 1.16 LAMA categories and Particulate Monitoring sites for the Southland Region.

In summary, the suggested LAMAs for Southland are:

Category 1 **Invercargill**
Category 1 **Gore**
Category 1 **Mataura**
Category 1 **Edendale**
Category 1 **Winton**

Other areas that may be considered for air quality management purposes are:

Category 2 Outer Invercargill
Category 2 Te Anau
Category 2 Nightcaps
Category 2 Wallacetown
Category 2 Makarewa
Category 2 Ohai
Category 2 Otautau

Category 3 All the rest

Thus there are 5 Category 1, 7 Category 2, and 1 Category 3 LAMAs

Table 1.16 provides a summary of past, current and planned $PM_{10}$ monitoring for the Southland Region.

Table 1.16 $PM_{10}$ monitoring undertaken in the Southland Region.

| Site | Lama Category | Dates of monitoring | Method of monitoring | Number of Exceedences recorded | Source of Information |
|---|---|---|---|---|---|
| Invercargill | 1 | Jul 03 to Dec 04 | High Volume | 4-2003<br>5- 2004 | ES 2004<br>ES 2005 |
| Gore | 1 | 2004 | High Volume | 7 | ES, 2005 |

The information contained in Table 1.16 identifies:

- **Gore**
- **Mataura**
- **Edendale**
- **Winton**

Category 1 LAMAs as potential gaps in the Southland $PM_{10}$ monitoring network.

*Sources of information*

*1) ES 2004*

*Annual Environmental Monitoring Report 2003/04 p 39-40*

*http://www.es.govt.nz/Departments/EI/EIreporting.aspx*

*2) ES, 2005*

*Air quality monitoring data provided by ES staff*

# Part 2. Monitoring-Network Enhancement

Part 1 of this report presented a region-by-region summary of $PM_{10}$ monitoring. This information was used to identify gaps in the $PM_{10}$ monitoring network of each region. Ideally, the ambient concentrations of $PM_{10}$ would be monitored in all Category 1 LAMAs. However, given resourcing and the numerous practical issues associated with ambient air quality monitoring, it is likely (at least in the short term) that not all Category 1 LAMAs within each region will be monitored. Should this situation arise, the obvious question to ask is.. *"If not all Category 1 LAMAs within a region can be monitored, which LAMA(s) should be given priority"?*

Part 2 of this report aims to provide ideas and methods that will allow Regional Councils to enhance their $PM_{10}$ monitoring networks in a practical and effective manner. Section 2.1 suggests how to prioritise $PM_{10}$ monitoring network gaps. Section 2.2 presents ideas on how many and where to establish monitoring site/s within a particular LAMA. Section 2.3 suggests a number of potential ways to assess/estimate compliance with the NES in Category 1 LAMAs that have no monitoring data.

## 2.1 Exploratory Prioritising of $PM_{10}$ Monitoring Gaps

This section covers an exploratory technique to help quantify the processes of assessing monitoring gaps. It is designed to inform further discussion (particularly at the planned workshop), and does not represent any final recommended methodology. The research aims to provide Regional Councils with a semi-quantitative process that will facilitate the prioritisation of Category 1 LAMAs that are currently not monitored. The priority ranking could be used to determine where Regional Councils could most effectively invest their air quality monitoring resources.

It is important to note that the process to prioritise Category 1 LAMAs for monitoring only provides a relative priority for LAMAs within a particular Region. It is beyond the scope of the proposed methodology to prioritise Category 1 LAMAs from different regions.

**Weighted Risk-Element Decision Matrix**

It is proposed is to use a Weighted Risk-Element Decision Matrix (WRE-DM) to prioritise Category 1 LAMAs that are currently not monitored. The use of the WRE-DM is a four-step process.

**Step 1. Identifying $PM_{10}$ Monitoring Network Gaps**

The information provided in Part 1 of this report is used to identify the gaps in the $PM_{10}$ monitoring network of Category 1 LAMAs for each region.

**Worked example Step 1: Manawatu-Wanganui.**

Category 1 $PM_{10}$ Monitoring Network Gaps:

- **Palmerston North**
- **Wanganui**
- **Taumaranui**
- **Taihape**

**Step 2. Risk-Element Data**

The WRE-DM uses four risk-elements for each of the Category 1 LAMAs being considered. Each of the elements has been chosen to represent a risk factor that contributes to the total potential $PM_{10}$ exposure within a LAMA. For simplicity the risk data used is limited to:

- Population, Emission and Land Area data for each LAMA
    - (data from Appendix 9 of the LAMA report)
- A simple meteorological element
    - (% calms in winter)

The specific risk-elements used are:

- Population - A measure of the number of people potentially affected by the pollutant
- Emission density - A measure of the amount of $PM_{10}$ emitted for per area of land (g $PM_{10}/km^2/day$)
- The percentage of time with calm (wind speeds $>2ms^{-1}$) conditions - A measure of how poorly (or well) the pollutants are dispersed

**Worked example Step 2: Manawatu-Wanganui.**

**Population, Emission and Land Area Data:** From Appendix 9 of the LAMA report

| LAMA | Population | Land Area ($km^2$) | $PM_{10}$ Emissions (kg/day) | $PM_{10}$ Emission Density (g $PM_{10}/km^2/day$) |
|---|---|---|---|---|
| Palmerston North | 61677 | 42 | 721 | 17.2 |
| Wanganui | 12594 | 10 | 346 | 34.6 |
| Taumarunui | 3984 | 10 | 55 | 5.5 |
| Taihape | 1803 | 5 | 22 | 4.46 |

**Meteorological data:** From the National Climate Database (CLIDB, http://cliflo-niwa.niwa.co.nz/)

| LAMA | % Calms (Hours with wind speed $<2ms^{-1}$) | Location of Climate Station | Station Agent Number | Year of Data (June to August) |
|---|---|---|---|---|
| Palmerston North | 35.1 | Palmerston North AWS | 3243 | 2001 |
| Wanganui | 28.4 | Spriggins Park | 3715 | 2001 |
| Taumarunui | 52.2 | *Turangi 2 EWS | 25643 | 2003 |
| Taihape | 54.0 | *Waiouru AWS | 3632 | 2001 |

* Closest site with full winter record of hourly wind speed.

**Step 3. Scaling and Weighting the Risk-Elements**

Each risk-element is scaled to provide a score out of 33 (a dimensionless value). This is selected so that the total of the three equally weighted elements totals 100. The scaled score provides an indication of relative risk for that particular element compared to the other LAMAs under consideration. A high score indicates relatively high risk.

The scores for the four individual four risk elements are summed to provide the Total Risk-Element score for a particular LAMA.

NB. In the worked example all three risk elements have been scaled to a dimensionless value of 33. This means that the three risk elements are contributing equally to the total score. There may be some justification for weighting the three risk elements differently according to the relative importance of a particular element within different regions. I.e. A particular risk-element becomes more (or less important). The weighting of the risk-element scores

**Worked example Step 3: Manawatu-Wanganui.**

**Risk-Element Scores**

| LAMA | Population ( /33) | Emission Density ( /33) | Pollutant Dispersion ( /34) | Total Risk-Element Score ( /100) |
|---|---|---|---|---|
| Palmerston North | 33 | 16 | 22 | 71 |
| Wanganui | 7 | 33 | 18 | 58 |
| Taumarunui | 2 | 5 | 33 | 40 |
| Taihape | 1 | 4 | 34 | 39 |

**Step 4. Incorporating $PM_{10}$ Monitoring Information**

A number of Category 1 LAMAs that are not currently monitoring $PM_{10}$, will have data from programmes run in the past. This "historical" data are likely to have been generated by long term monitoring programmes that have terminated or short-term "screening" campaigns. The monitoring methods used range from Standard techniques through to screening sampling methods, such as the mini-volume sampler.

Step 4 uses historical monitoring data (if they exist) to develop a qualitative monitoring-factor. This monitoring-factor is used to scale the Total Risk-Element Score that determines the final priority order for Category 1 LAMAs not monitored. The assignment of qualitative monitoring-factors is described in the following Table.

**Qualitative Monitoring-Factor**

| $PM_{10}$ Monitoring Results | Monitoring-Factor to Apply to Total Risk-Element Score. |
|---|---|
| No monitoring results available | 1 |
| Monitoring results suggest $PM_{10}$ exceedence unlikely | 0.75 |
| Monitoring results ambiguous or suggest $PM_{10}$ exceedence possible | 1.5 |
| Monitoring results show $PM_{10}$ Exceedences occur | 2 |

.

**Worked example Step 4: Manawatu-Wanganui.**

**Incorporating $PM_{10}$ Monitoring Information**

| | Sub-Total Weighted Risk-Element Score | Monitoring-Factor | Final Score |
|---|---|---|---|
| Palmerston North | 71 | 0.75 | 54 |
| Wanganui | 58 | 0.75 | 43 |
| Taumarunui | 40 | 2 | 81 |
| Taihape | 39 | 2 | 78 |

**Monitoring Priority List for Category 1 LAMAs not yet monitored.**

| LAMA | Monitoring Priority |
|---|---|
| Palmerston North | **3** |
| Wanganui | **4** |
| Taumarunui | **1** |
| Taihape | **2** |

## Discussion of Exploratory Prioritising of $PM_{10}$ Monitoring Gaps

The Weighted Risk-Element Decision Matrix has been designed with the aim of providing Regional Councils with a semi-quantitative process to facilitate the prioritisation of Category 1 LAMAs that are currently not monitored.

The methodology described could be refined and/or improved depending on individual Council's needs, issues and the data that is available. It is recommended that before any Council uses the WRE-DM they should give due consideration to the following issues:

1) This method should only used to provide an indicator of priority sites. It should NOT used to generating a "definitive priority list". Other factors, including monitoring and fieldwork practicalities will influence where monitoring sites will be located.
2) The risk assessment approach described above is based on likelihood of exceeding the NES. There are alternative and perhaps in some cases more useful/appropriate approaches to base the risk assessment on: e.g.
    - Potential for greatest no of heath impacts i.e., greatest no of people affected
    - Greatest potential for health impacts (say for a single susceptible person) - ie worst case location to live for an individual
3) Small differences in Final Scores (say +/- 5) should not be considered significant.
4) Additional or alternative Risk-Elements may be introduced or substituted into the matrix, depending on data availability and/or specific Regional Council needs.
5) There may be more qualitative ways to incorporate any available $PM_{10}$ monitoring data.
    - Use the maximum recorded concentration as a risk factor (if all sites have some historic monitoring data)
    - Use the maximum recorded concentration as substitute for the emission and meteorological risk factors.
6) There may be more appropriate ways to weight the three (or more) risk elements rather than giving them equal weight.
    - Perhaps population should be more influential? This would weight the risk assessment toward potential for greatest number of people affected.
    - Perhaps health impacts should be more influential? This would weight the risk assessment toward potential for the largest adverse health effect (say for a single susceptible person). I.e. the worst-case location for an individual potential for health impacts.

In summary, the WRE-DM presented above should be used as a concept and/or framework upon which Councils can develop and improve to meet their individual needs and available data.

## 2.2 Number and Siting of New Monitors within Category 1 LAMAs.

## Scope

This section addresses the question of "*Where should monitors be placed in an airshed, and how many are needed?"*

There are several different approaches, followed by different authorities, usually for different purposes.

A common target adopted in many countries (European Union, USA, Australia, and to some extent previously in New Zealand), is to have a certain number of monitors per population – say 1 per 50,000 people. This is usually qualified slightly in terms of the size of the city – with smaller cities (<50,000) still having a monitor, and very large dense cities (>1,000,000) perhaps not needing as many.

A second methodology is using explicit and detailed airshed modelling to identify regions of interest, and place monitors at these locations.

A third, perhaps even more common, is to locate monitors at perceived hot spots, or at sensitive locations. These can be determined by air pollution criteria, but also by political pressures or community concerns.

Tempered by all of these requirements is often a practical criterion of finding a suitable site at or near the location required. The siting requirements (not specified in the regulations) need to be determined. The usual criteria (covered by standards such as *Ambient Air – Guide for the Siting of Sampling Units,* AS2922 – 1987, or similar US and EU ones) do not always apply, although some aspects, such as clearance from obstacles must still be used.

However in New Zealand, the National Environment Standards have created a particular and specific requirement for monitoring that is not precisely equivalent to any of the methods discussed above. This is (quoting from the regulations):-

"**15 Regional council must monitor air quality if standard breached**
If it is likely that the ambient air quality standard for a contaminant will be breached in an airshed, the regional council must:

(a) monitor the airshed in relation to that contaminant; and
(b) conduct the monitoring
  (i) in that part of the airshed where
    (A) there are one or more people; and
    (B) the standard is breached by the greatest margin or the standard is breached the most frequently, whichever is the most likely; and
  (ii) in accordance with the relevant method listed in Schedule 2."

The intent of this is clear, but the method for deciding how it is achieved is complex.

## Issues

There are a number of issues that need to be understood and taken into account when designing a monitoring system for standards compliance.

**Airshed concept:** The 'airshed' as used in the regulations is not an airshed in the normal physical sense of the term. It is a management construct and does not necessarily represent any geophysical airshed. Some Councils have set 'airsheds' that are close to true airsheds, but others have not. This presents an issue for determining a monitoring location, because a standards 'airshed' may have fine scale features within it that do not relate to geophysical parameters such as pollution transport and dispersion as indicated by modelling.

**Airshed size:** Some 'airsheds' are large – and indeed may comprise several separate true airsheds, each with its own features. A monitor that records concentrations in one part of such an 'airshed' may not reflect conditions in another part. This is not universal, since there will be common features across

the different airsheds – such as traffic and domestic emissions – and it might not be difficult in practice to select the worst area as required by the regulations.

**Local features:** The regulations are very clear on requiring monitoring "where there are one or more people". The Guidelines and common sense mean that this is not necessarily applied to the absolute worst case (perhaps a cyclist travelling in the wake of a very dirty truck), but can be applied to street level exposure. At the extreme, this could mean having a monitor located at the curb, on all the busiest intersections.

**Worst location**: Identifying the worst location is not a straightforward task. Many monitors have been sited almost on the basis of trial and error, or using simple subjective assessments. This is not unreasonable, but can lead to circumstances where the worst location is missed – perhaps significantly. It has been the experience in cities that have multiple long term monitors (eg Auckland, Wellington, and Christchurch) that sites that were thought to be peak sites have not always turned out to be so, and vice versa.

**Worst frequency:** The regulations require monitoring where the amount of any likely exceedence is greatest OR the frequency of exceedence is highest – which ever is the most likely. This is a difficult assessment, because (a) these two circumstances will in general occur at different locations, and (b) they may be of different importance in different years. (For instance a low emission, warm and windy year might result in 2-3 large exceedences at location x – say due to a couple of calm days near a particular source, alternatively a high emission, cool and calm year might result in 30-40 smaller exceedences at location y – say due to widespread domestic heating emissions). Ideally, the monitoring design should include a monitor for each of these circumstances, even if there are several within an 'airshed'.

**Siting constraints:** Even once a suitable location has been identified, it can be difficult to actually locate and run the necessary equipment at the exact place desired. This is particularly true in built-up areas. The constraints are not just with finding an owned or leased site to place the monitor, but also ensuring that nearby residents are not adversely affected. This occurs particularly with PM10 monitoring equipment that can have a noisy pump. A further issue arises in that the siting criteria are not defined. If the usual criteria were to be used, the intent of the standards regulations may not be met. New criteria may need to be established.

**Modelling:** A dilemma exists if monitoring data is to be used for purposes other than standards compliance. For instance airshed modelling requires both input data and data for validation. Models typically work on grid cells of the order of 0.5 km to 3 km, and thus they represent spatial averages over these scales. They have difficulty with 'hot spots' on smaller scales – and typical traffic related hot spots might be just a few tens of metres in scale. Ideal sites for use in modelling are those that are representative over scales of a few kilometres. Sites developed for standards compliance will not generally be the same. Any monitoring network should have sites that fit at least both of these purposes.

## Methodologies.

How are the number and sites of monitors to be decided?

**Existing ambient sites:** Firstly, in many areas, some monitoring sites already exist, which in some cases have been run for many years. As a general principal, a long term monitoring site should not be relocated or discontinued. Air pollution effects and monitoring data are highly variable from year to year, and it is only when records become longer than 5 years that such variabilities can start to be identified. Although the standards require that monitoring be conducted at peak sites, it can be counterproductive (and expensive) to continually move monitoring sites around trying to find a peak site that may be quite elusive, or even moving around itself. The value of data from a site increases greatly as the length of continuous record increases.

**Existing resource consent sites:** Most Councils rely on their own monitoring sites to assess air quality. However there are a significant number of monitors run by consent holders under conditions. In some cases data from these find their way into official records – but for many they do not. These

industry-run sites can have variable data quality, but some have long term valuable records that could be used for the standards compliance purposes.

**New sites – need identified:** Where a need has already been identified, say through some scoping monitoring, or through some airshed modelling, or simply by public pressure – then installation should be fairly straightforward. It is recommended that at least one full year of monitoring be completed before any re-location is considered.

**New sites – exploratory:** It can be difficult and expensive to place 'trial' monitors – especially for $PM_{10}$ – since sheds, fences, power etc all needs to be organised. Previously a number of Councils have run 'MiniVol' type programmes, where a battery powered small sampler is deployed to test the site choice. These can be useful, but time is needed to assess the data. Another valuable approach is to have a fully mobile site – located inside a caravan. This is a little more expensive that a fixed site – but again has been used by a few Councils. It is difficult, and perhaps not appropriate to leave these at one location for a year or more, but even 1-2 months sampling at peak times (usually winter) can give excellent information on expected conditions at the site and relativities between sites, particularly if data from different sites can be compared to results from another permanent site.

**Site density:** Determining the ideal number of monitors for a given airshed is a problem that is not easy to solve. One concept to apply, is the 'sphere-of-influence' idea. Just how far away from the monitor do sources affect the concentrations measured. For flat uniform areas (such as Christchurch, Palmerton North, Hamilton) this can be many kilometres. For hilly complex areas (such as Auckland, Wellington, Dunedin) this can be less than 1 km. It is relatively straightforward to test this after a few years of data are available. For instance the auto-correlation between the Mt Eden and Penrose sites in Auckland (about 5 km apart) is very strong – when there are high concentrations at one, there are also high correlations at the other. However this correlation weakens substantially going to Takapuna (10 km further north). The process of deciding this before data sets are available is subjective at best, with the only real quantitative tool being extensive airshed modelling. This has only been conducted for Auckland, Christchurch and Nelson, although some work has been done and is on-going in Wellington, and Northland, and modelling investigations are underway (2005) for Hastings/Napier and Wanganui/Manawatu.

**Relocating/Removing a site:** If analysis of data from a particular site after some period shows it may NOT be representing the "people" or "peaks" or "frequency" requirements of the regulations it should be considered for relocation. However this must not be undertaken lightly – it would be very easy to move it to a similar or worse site, and lose the advantage created by multi-year record lengths. If the site is "good" from the point of view of representativeness of a particular area, and from its exposure and operability – then it should remain. Sites should only be moved if there are very well defined and justified reasons for doing so, based on (a) new modelling results, (b) significant shifts in emissions sources, (c) severe operating restrictions.

## Summary and Recommendations

The question of where monitors should be, and how many are needed is never going to be answered precisely. This section has discussed some of the issues to be considered and the factors that need to be assessed in siting and monitoring decisions. There are five overall recommendations:

1. Do not compromise quality, either in the monitoring equipment, the monitoring operations/schedule, or in the local site applicability.
2. The minimum useful period for standards compliance analysis is one year.
3. Long term records are more valuable than short ones – do not relocate monitors without very good reason.
4. Large or complex airsheds will likely require more than one monitoring site in order to assess all of the criteria required in the standards regulations.
5. Regularly review the data, preferably in association with airshed modelling and reviews of the local emissions sources.

## 2.3 Assessing Compliance in Category 1 LAMAs that have no Monitoring Data

Ideally all Category 1 LAMAs would be monitored for $PM_{10}$. However, in reality this may not occur due to the resourcing required and other practical issues that are associated with monitoring $PM_{10}$ in ambient air. The aim of Section 2.3 is to provide some suggestions on how assess compliance in Category 1 LAMAs that have no monitoring data. A number of options are discussed below.

**Set Up New Sites for "High Priority" Gaps in the Monitoring Network**

The first step is to prioritise monitoring network gaps using the approach described in section 2.1. The second step is to monitor as many of the high priority Category 1 LAMAs as practical with the resources available. Once the resources available for permanent monitoring sites are exhausted, then undertaking one or more of the following actions may prove helpful.

**"Screening" Monitoring**

Screening monitoring uses relatively cheap and easy to set up sampling methodologies. E.g. Mini-vol samplers. The data collected during a screening monitoring programme will not meet the requirements of the NES, but can provide indicative and very useful information. It may be useful to run screening monitoring programmes for preliminary investigations into Category 1 LAMAs which are not monitored. These methods/instruments can be used to assess and/or confirm the monitoring priority of LAMAs within a Region. Screening monitoring could also be used to choose the most useful permanent or campaign site/s within a particular Lama.

**"Campaign" Monitoring**

Campaign monitoring involves using standard monitoring methods for defined periods of time usually during the months of the year when the highest pollution levels are expected. Mobile air quality monitoring laboratories can be very useful for campaign monitoring. The advantage of campaign over screening monitoring is the superior data quality produced by the standard methods of monitoring which can be set up in air quality monitoring trailers/caravans. One mobile air quality monitoring laboratory could be rotated over a number of LAMAs or sites within a Lama during one winter. A particular campaign monitoring programme can be repeated at a later point in time in an attempt to track changes in air quality. The frequency at which the campaign is repeated needs careful consideration. It is worth noting that the most useful data to assess long-term changes in air quality is obtained from permanent sites with long-term data records.

**Developing and Using "Proxy Measurements"**

There is no real substitute for good quality - long record monitoring data. But in locations where PM monitoring is not practical and/or economic there may be some value gained by using campaign monitoring data and developing a semi-quantitative and robust proxy measurement methodology. E.g. Use of $PM_{10}$ measurements from close by or from a "similar source/town". There are a number of criteria that would need to be met before this method would be suitable. In particular a good correlations between datasets would be required.

Nelson City Council (NCC) have used this approach. NCC found a relationship (with an r-squared value of about 0.9) between the data collected at their long-term monitoring site (Nelson City Valley) with a campaign monitoring site in Tahuanui (3-4 km away but in a separate airshed). This allowed NCC to hindcast the number of exceedences experienced in Tahuanui based on the monitoring data collected at the permanent site in Nelson city. Following and as a result of the proxy measurement work, NCC have set up a permanent monitoring site in Tahuanui.

# Part 3. Knowledge Gaps

The aim of Part 3 is to highlight and discuss our current knowledge (as opposed to network) gaps in $PM_{10}$ monitoring. Section 3 will

- Briefly outline five $PM_{10}$ monitoring issues and put these into the New Zealand context
- Describe what (if any) New Zealand data exist
- Make some preliminary recommendations on how this issue may be moved forward by the FRST programme in collaboration with other stakeholders.

## 3.1 Comparing Different Methods of Monitoring PM

**Introduction**

The NES regulations define which $PM_{10}$ monitoring methods are to be used to determine compliance with the $PM_{10}$ Standard. Schedule 2 of the regulation provides for two methods for monitoring fine particulate – both of them gravimetric. However included in these gravimetric methods are "equivalent" methods which use alternative technology to determine $PM_{10}$ concentrations in ambient air. In this context 'equivalency' is a formalised criterion that implies some defined approval from a suitable regulating organisation such as the Ministry for the Environment, Standards NZ/Australia, US EPA, etc.

"Appendix 3: Fine Particulate Monitoring Methods" of the NES Users Guide presents a full list of acceptable methods which can be used to determine compliance with the NES $PM_{10}$ Standard. Appendix 3 lists a total of 3 Australian and 21 US methods for monitoring $PM_{10}$. These include, high and low volume gravimetric methods, Beta Attenuation Monitors (BAMs) and Tapered Element Oscillating Microbalances (TEOMs). This comprehensive list of methods covers current and commonly used technology and will be updated regularly to reflect technology changes. The different methods of determining particle mass concentrations covered in Appendix 3 are described and compared in detail by McMurry (2000).

An upgraded version of the TEOM instrument has recently become available. The Rupprecht and Patashnick (R & P) Series 8500 TEOM-FDMS $PM_{10}$ unit is designed to overcome the issue of losing volatile material before the PM10 is measured. The Filter Dynamics Measurement System (FDMS$^{TM}$) unit accounts for both the volatile and non-volatile components of particulate matter (PM), and reporting the combination as a mass concentration result. This is done by measuring the volatile portion of the sample independently from the total incoming sample, and using this fraction in calculating the PM mass concentration. The TEOM-FDMS is one of the instruments listed as an "acceptable method" to monitor fine particulate in MfE's User's Guide to the National Environmental Standards.

Ideally collocated measurements using different technologies would produce identical particle mass concentrations. However, in reality this is not the case. It is acknowledged that there is significant potential for different results to be obtained using the different methods (MfE 2000). This is primarily because the various technologies measure slightly different properties of particles suspended in air. The potential difference in results has been a "*hot topic*" in the air quality field for a number of years. Work on comparing the different methods of monitoring fine particulate material has produced a significant volume of scientific literature.

The European Community (EU) Working Group on Particulate Matter has provided guidance to its Member States on $PM_{10}$ monitoring and inter-comparison reference methods (Williams and Bruckmann, 2002). The INTERCOMP2000 study (Hitzenberger *et. al.,* 2004) was conducted to compare aerosol samplers and methods to measure various aerosol properties. One of the three general program objectives of the US Particulate Matter "Supersites" Programme is to conduct methods-testing and to obtain atmospheric measurements that will compare and evaluate methods of characterising PM (USEPA, 2000). Numerous studies have compared gravimetric and TEOM instruments. Three examples of these studies are provided by Charron *et al.* (2004), Price *et al*. (2003), and Ayers *et al.* (1999). The Peer Review Committee of Australia's the National Environmental Protection (Air Quality) Measure (NEPM) has also explored the relationship between TEOM and high-volume sampling (EPHC 2001).

The specific aims of these studies differ, but generally they seek to quantify the differences produced by the varying monitoring methods. A number of studies have gone on to develop "correction factors" which enable $PM_{10}$ data collected using one method to be compared to an "equivalent" set of data generated by a different monitoring method at a particular site. Some attempts have been made to collate data collected at a number of different sites and to develop default or generic correction factor(s) for locations where inter-comparison studies have not been undertaken.

**Why is this issue important in NZ?**

In New Zealand, the responsibility for monitoring air quality rests with each individual Regional Council (RC), and not with one Central Government Department. Over the past decade, the monitoring programmes of each of the Councils have developed using different technologies. This situation has resulted in a reasonably diverse range of instrumentation being used to monitor $PM_{10}$. However, $PM_{10}$ monitoring is most commonly carried out using one of three methods:

- Gravimetric methods (High and low volume technologies)
- BAMs
- TEOMs

These three methods are all contained in the list of "acceptable methods" provided in the NES Users Guide. Therefore the use of all three methods is likely to continue into the foreseeable future.

The NES users guide touches on one of the most significant implications of using the different methods of monitoring $PM_{10}$ in Section 3.4.2 – Monitoring of Fine Particulates. The users guide notes that *"with respect to TEOMs, the intent is to continue with current best practice as outlined in the* "*Good Practice Guide for air quality monitoring and data management" (MfE, 2000). This requires the development of site-specific adjustment factor or the use of Filter Dynamics Measurement System (FDMS), to ensure that the volatile fraction is not lost*".

Given the

- results of overseas studies which highlight different results obtained using different methods,
- requirements of the NES to accurately monitor and report $PM_{10}$ data,
- implications of a particular RC experiencing an exceedence of the standard, and the
- importance of monitoring data in tracking progress toward achieving the NES $PM_{10}$ standard,

it is highly desirable to understand and quantify the differences (if any) these three different methods of monitoring particulate matter produce in the New Zealand environment.

**What comparisons have been undertaken in NZ?**

A number of organisations throughout the country have recognised the importance of understanding the difference between results produced by various methods of monitoring particulate matter. The following gives a brief overview of the data collected.

**Environment Canterbury:**

ECan are currently running a programme with the objectives of:

- Assessing the various methods of measuring $PM_{10}$ in Christchurch and Timaru
- Determining equivalence of these methods with a reference method
- Confirming a method to be used to report against NES in Canterbury
- Constructing a consistent dataset of PM10 concentrations - 1996 to 2004

The programme is focusing on data collected in St Albans (Packe Street and Coles Place). The instrumentation used to collect the data includes TEOM (25, 30, 40 and 50$^{o}$C), TEOM FDMS, BAM and high-volume gravimetric sampling.

**Ministry for the Environment**

MfE have co-ordinated a co-location study at the Burnside site, Christchurch in 2005. This is a collaborate project between MfE, ECAN, Watercare and Landcare. The objectives are to compare data from a TEOM (40$^{o}$C) TEOM FDMS, BAM (FH62) and high-volume gravimetric sampling.

The high-volume samplers were run midnight to midnight on a 1 day in 6 basis from the end of February to May. The frequency increased to Tuesdays, Thursdays and Saturdays from May to the end of July. The TEOM FDMS and FH62 have been operational throughout this period. A TEOM at 40C has been operating since May.

**Auckland Regional Council**

ARC have operated TEOMs, BAMs and high-volume samplers at four sites around Auckland over the years 1997 to 2003. The objectives of this work were to:

- Examine discrepancies between measurements obtained from TEOMs, BAMs and high-volume samplers.
- Provide a means by which TEOM and BAM data can be systematically adjusted to an “equivalent” gravimetric measurement.

**University of Canterbury**

The University of Canterbury have compared mass concentration data generated by three co-located particulate monitors, TEOM (40$^{o}$C), low-volume gravimetric sampler and a DustTrak. The instruments were operated in Christchurch during winter of 2004.

**Greater Wellington**

Greater Wellington have been operating a GENT Sampler ($PM_{10}$, $PM_2$ and $PM_{10-2}$), TEOM and high volume gravimetric sampler at their Masterton Site (Wairarapa College) for two years (2003 and 2004).

**NIWA**

NIWA have operated a TEOM FDMS and low volume-gravimetric sampler (Partisol) at a heavily trafficked intersection in Newmarket, Auckland. The instruments were operated over the months May and June 2005.

**What have these data told us?**
While a significant body of data has been collected throughout NZ over the last 4 or so years, not all the data sets have been analysed or reported on.

ARC have produced a draft report on their study. The preliminary conclusions are that:

- Comparisons of the gravimetric and TEOM data displayed a lot of scatter but some observable trends existed.
- Air temperature was identified as a possible driver of TEOM anomalies. TEOM measurements tended to be higher that gravimetric measurements when the temperature was above 18$^{o}$C and lower when the temperature was below 18$^{o}$C.
- It is difficult to produce a systematic means by which TEOM data can be converted to equivalent gravimetric measurements.
- Comparisons of the gravimetric and BAM data showed better correlation but had no apparent link with temperature or humidity.
- BAM concentrations tended to be higher than gravimetric measurements.

The University of Canterbury study has been submitted to Atmospheric Environment (Kingham *et. al.,* 2005). The outcomes of this work included:

- An algorithm which was used to adjust TEOM data to an equivalent high-volume reading
- The DustTrak required a substantial correction factor to make data comparable
- The MiniVol sampler did not correlate well with other instruments.

The ECAN work will be reported on in their 2005 Annual Air Quality Monitoring report. But the initial findings have lead ECAN to apply an adjustment factor to historical TEOM (40$^{o}$C) data.

No analysis or reporting has been undertaken for the Greater Wellington, MfE or NIWA studies.

**Recommendation**
Objective 6 of the Foundation programme should invest time and/or resources into a New Zealand based nationwide study that:

- Quantifies the differences produced by the varying $PM_{10}$ monitoring methods
- Explains the reasons for any differences observed
- Aims to develop “correction factors” which enable $PM_{10}$ data collected using one method to be compared to an “equivalent” set of data generated by a different monitoring method at a particular site
- Collates data collected at a number of different sites and evaluates these in the context of developing default or generic correction factor/s
- Determines if the NES requirement to “site specific” adjustment factors is warranted

Options, which would achieve the recommended outcomes, include:

- Review Other Programme Outcomes
  - Wait until the individual groups have reported on the current studies. Review these outcomes in respect to the FRST Objective 6 aims
- Collaborative Study
  - Design a methodology which aims to analyse all the data collected in NZ in an effective, useful and nationally consistent manner
  - Form a Working/Advisory Group with Stakeholders
  - Request access to the data that has been collected to date
  - Carry out the analysis according to the methodology and report findings and make recommendations
- FRST Standalone Study
  - Design and carry out a field campaign that would provide the quality and quantity of data which would allow the desired outcomes to be achieved

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## 3.2 $PM_{2.5}$ in Urban NZ

**Introduction**

Atmospheric particulate matter consists of a wide range of material arising from a variety of sources. Particulate matter is measured in a range of metrics. The most commonly used metric is $PM_{10}$, which describes the mass of particles in the atmosphere with a diameter less than 10μm. $PM_{2.5}$ is less commonly measured.

The characteristics and sources of $PM_{2.5}$ and $PM_{10}$ can be very different. $PM_{2.5}$ tends to be a result of combustion activities (solid-fuel home heating, motor vehicles and industrial fuel use). $PM_{2.5}$ can also be formed as a result of reactions between various atmospheric components such as sulphur dioxide, nitrogen oxides and volatile organic compounds. The larger size fraction $PM_{2.5-10}$ is generally emitted from mechanical sources such as windblown dust, vehicles travelling on unpaved roads, bulk handling facilities, mines and crushing grinding operations.

There have been a number of public health effects studies carried out on a range of PM parameters including $PM_1$, $PM_{2.5}$ and $PM_{10}$ particle numbers and surface area. Much of this data comes from the US however recently studies have also been conducted in Europe and the UK. These epidemiological studies show a correlation between exposure to particles and adverse health effects. Associations have been observed with $PM_{10}$, $PM_{2.5}$ and $PM_{2.5-10}$. There is considerable debate about the relative effects of the various size fractions. However, generally studies show a stronger association between adverse health effects and $PM_{2.5}$ than is observed with $PM_{10}$. This is thought to be principally a result of $PM_{2.5}$ penetrating deeper into the lungs than the larger size fraction. The studies also strengthen the conclusion that the active component of particulate matter resides mostly in the fine fraction of the material.

Internationally there has been a shift in the management of air quality to respond to the findings on $PM_{2.5}$. In USEPA's National Ambient Air Quality Standards were reviewed in 1997 and two new primary $PM_{2.5}$ standards were introduced. (65 $\mu gm^{-3}$, 24-hour average and 15 $\mu gm^{-3}$ annual average) (USEPA 1997). Canada also recognises the fine fraction of particles as having the greatest effect on human health. In June 2000 the Governments of Canada, the Provinces and Territories set a $PM_{2.5}$ standard of (30 $\mu gm^{-3}$, 24-hour average) (CCME 2000). The UK have not established a $PM_{2.5}$ standard. However their Expert Panel on Air Quality have recognised that $PM_{2.5}$ might be more representative of the toxic fraction of particulate pollution and that a $PM_{2.5}$ standard may be a highly desirable objective (DEFRA 2005). The UK air quality standards are being reviewed during 2005. In 2003 Australia varied their National Environmental Protection (Ambient Air Quality) Measure (NEPM) to introduce Advisory Reporting Standards for $PM_{2.5}$ and a protocol of monitoring and reporting of $PM_{2.5}$ (NEPC 2003). The European Union's Clean Air for Europe (CAFÉ) project has produced a position paper on particulate matter. The position paper recommended the use of $PM_{2.5}$ rather than $PM_{10}$ as the principal metric for assessing exposure to particulate matter (Meadows and Seifert 2003). Another of the CAFÉ paper's recommendations was to consider (as a starting point) a target value for $PM_{2.5}$ of around 35 $\mu gm^{-3}$ (not to be exceeded more than 10% of the days of the year).

With the implementation of $PM_{2.5}$ standards overseas, the respective environmental regulatory bodies have had to assess whether or not the methods used to monitor $PM_{10}$ were also appropriate and effective to monitor $PM_{2.5}$.

**Why is this issue important in the NZ context?**

In New Zealand, the National Environmental Standard for particulate matter has been set on $PM_{10}$ at the value of 50 $\mu gm^{-3}$ (24-hour average). No standard has been set for $PM_{2.5}$. However in the Ambient Air Quality Guidelines (MfE 2002) which preceded the NES it was noted that

> *" Recent research has shown that particles less than 2.5 microns in diameter ($PM_{2.5}$) may be responsible for specific health effects caused by fine particulates. We therefore need to increase our understanding of $PM_{2.5}$ in New Zealand and to promote monitoring and source assessments. A monitoring value of 25 $\mu gm^{-3}$ (24-hour average) can be used for assessing monitoring results and to judge whether further investigations are needed to quantify $PM_{2.5}$ sources. In suggesting this value, the Ministry aims to promote $PM_{2.5}$ monitoring and assessment. It is premature to use $PM_{2.5}$ as a target for airshed management until further research can accurately determine its specific health effects and its sources."*

In many areas that experience frequent exceedences of the standard the predominant source of particulate matter tends to be emissions from solid-fuel home heaters. Given the combustive source of this particulate matter, it is likely that a relatively large proportion of the PM falls within the fine fraction ($PM_{2.5}$). Therefore $PM_{2.5}$ is an issue worthy of further investigation in New Zealand.

**What $PM_{2.5}$ data has been collected in NZ?**

A number of organisations throughout the country have recognised the potential importance of $PM_{2.5}$. The following gives a brief overview of the data that has been collected.

**Auckland Regional Council**

ARC are currently monitoring for $PM_{2.5}$ at four sites (Mount Eden, Penrose, Khyber Pass and Queen Street) in Auckland. The monitoring is being undertaken with a frequency of one day in three using Partisols. $PM_{2.5}$ has been monitored at the Mount Eden and Penrose sites since 1997. Monitoring $PM_{2.5}$ at Khyber Pass and Queen Street began in 2002. $PM_{2.5}$ was also monitored at Takapuna in 1996 using a TEOM.

**Greater Wellington**

Greater Wellington have been operating a GENT Sampler ($PM_{10}$, $PM_2$ and $PM_{10-2}$), at their Masterton Site (Wairarapa College) for two years (2003 and 2004).

**Nelson City Council**

Nelson City Council monitored for $PM_{2.5}$ and $PM_{10}$ using collocated Partisol Samplers during 13 days of the 2002 winter.

**Environment Canterbury**

Environment Canterbury has monitored $PM_{2.5}$ sporadically at Coles Place, Saint Albans since May 2001. The instrument used was a TEOM. $PM_{2.5}$ has also been monitored at Sumner Primary School (Oct 01 to Feb 02) an in Kaikoura (Apr to May 02) using a TEOM.

**What has this data told us?**

While a some $PM_{2.5}$ data has been collected throughout NZ over the last 4 or so years, not all the data sets have been analysed or reported on.

The annual average $PM_{10}$ and $PM_{2.5}$ concentrations measured at Coles Place by ECAN in 2003, show that approximately 55% of $PM_{10}$ is $PM_{2.5.}$ There are indicators that suggest the percentage of $PM_{2.5}$ is higher during winter months. During 2003 concentrations of $PM_{2.5}$ measured at Coles Place exceeded MfE's monitoring value of 25 $\mu gm^{-3}$ (24-hour average) a total of 17 times. (Data taken from- ECAN 2003).

The annual average $PM_{10}$ and $PM_{2.5}$ concentrations measured at Mount Eden, Penrose, Khyber Pass and Queen Street by ARC in 2003, show that between 51 and 68% of $PM_{10}$ is $PM_{2.5.}$ The 2003 data shows that the ratio of $PM_{2.5}$ to $PM_{10}$ during winter months is similar to the annual average (ranges between 57 and 60%). During 2003 concentrations of $PM_{2.5}$ measured at the four sites exceeded MfE's monitoring value of 25 $\mu gm^{-3}$ (24-hour average) a combined total of 8 times. (Data taken from ARC 2004).

The $PM_{10}$ and $PM_{2.5}$ concentrations measured at Nelson in 2002, show that between 60 and 98% of $PM_{10}$ is $PM_{2.5.}$ The 2002 data shows that the average ratio of $PM_{2.5}$ to $PM_{10}$ during winter months monitored is 82%. The concentrations of $PM_{2.5}$ measured in Nelson exceeded MfE's monitoring value of 25 $\mu gm^{-3}$ (24-hour average) a total of 8 times of the 13 days monitored. (Data supplied by NCC).

**Recommendation**

Objective 6 of the Foundation programme should invest time and/or resources into a New Zealand based and nationwide study that:

- Quantifies the relationship between $PM_{10}$ and $PM_{2.5}$ in urban New Zealand
- Explores and explains any regional differences in the ratio of $PM_{10}$ and $PM_{2.5}$

- Explores and explains any seasonal differences in the ratio of $PM_{10}$ and $PM_{2.5}$
- Reviews the methods used to monitor $PM_{2.5}$ in New Zealand and compares these with the methods attached to the overseas $PM_{2.5}$ standards
- Reviews the $PM_{2.5}$ monitoring network in New Zealand in terms of the numbers of monitors and their siting

Options, which would achieve the recommended outcomes, include:

- Review Other Programme Outcomes
    - Wait until the individual groups have reported on the current studies. Review these outcomes in respect to the FRST Objective 6 aims.
- Collaborative Study
    - Design a methodology which aims to analyse all the data collected in NZ in an effective, useful and nationally consistent manner
    - Form a Working/Advisory Group with Stakeholders
    - Request access to the data that has been collected to date
    - Carry out the analysis according to the methodology and report findings and make recommendations
- FRST Standalone Study
    - Design and carry out a field campaign that would provide the quality and quantity of data which would allow the desired outcomes to be achieved.

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## 3.3 Measuring Particle Numbers rather than Particle Mass

The purpose of this section is to:

- Summarise the issues relating to the measurement of particle numbers
- Evaluate the benefits of measuring particle numbers in New Zealand
- Evaluate methods for measuring ambient air particle numbers
- Make recommendations relating to the measurement of particle numbers in New Zealand

**Issues**

Interest in the collection of particulate data in terms of particle numbers has increased over the last five years as health researchers have investigated biological mechanisms responsible for adverse health impacts associated with concentrations of particles in the air. A number of different aspects of particles have been considered including particle mass, number, surface area, volume, chemical toxicity, acidity, solubility and allergenic properties of particles from pollen, fungi moulds or endotoxins (Watson and Chow, 2005).

There are ranges of different health impacts that have been found to be associated with exposure to ambient air concentrations of $PM_{10}$. It is probable that different particle properties are responsible for causing different health impacts. For example, associations between measured $PM_{10}$ concentrations and lung cancer are most likely related to particle composition, whereas particle size or number may be more of a determinant in respiratory related impacts. An evaluation of the potential role of different particulate characteristics in causing adverse health impacts is included as a project output for the health impacts stream of the FRST programme.

One of the limitations in evaluating the impact of particle numbers on health, in an observational/ epidemiological capacity, is the limited amount of ambient air quality monitoring that collects data on particle numbers. Air quality guidelines and standards for $PM_{10}$ are based on particle mass and are likely to remain so unless another variable is found to be more closely related to adverse health impacts. Consequently the majority of long-term air quality monitoring programmes are designed around collecting data on mass concentrations.

**Benefits**

The benefits of collecting ambient air quality monitoring data for particle numbers would assist in the understanding of relationships between sources and particle numbers, and in some locations the relationship between health impacts and particle numbers. The latter would depend on the size of the area, as many small urban areas of New Zealand would be unsuitable for epidemiological studies because of the small population and subsequent difficulties in achieving sufficient power in the relationships to demonstrate impacts.

There is little motivation for Regional Councils in New Zealand to undertake air quality monitoring for particle size because standards have been set based on $PM_{10}$ mass concentrations. Contribution to scientific understanding, the main benefit of monitoring for particle numbers, is not a primary role or priority for Regional Councils, who are responsible for air quality monitoring and management in New Zealand.

If monitoring of particle numbers were to be carried out in New Zealand it is more likely to be associated with air quality related research projects such as the current FRST programme, Health Research Council (HRC) funded activities or university related projects.

**Monitoring methods**
A number of monitoring methods are available for measuring particle numbers. These tend to rely on one of the following techniques.

**GRIMM**
The only monitoring method that can measure particle numbers that is used for air quality monitoring in New Zealand is the GRIMM model 1.105 sampler. In fact, GRIMM technologies incorporated produce a number of samplers that can measure particle numbers, which are detailed on their website:
http://www.dustmonitor.com/General/products.htm#NANO_PARTICLES/RESEARCH

Although some monitoring has been carried out using the GRIMM in New Zealand these studies have focused on $PM_{10}$ mass rather than particle numbers.

The GRIMM 1.105 sampler currently used in New Zealand is referred to as an aerosol spectrometer and is based on a single particle scattered light method. The scattered signal from the particle passing through a laser beam is collected at approximately 90° by a mirror and transferred to a recipient diode. After a corresponding reinforcement, the signal of the diode passes a multi-channel size classifier. A pulse height analyser then classifies the signal transmitted in each channel.

The lowest size fraction able to be measured varies with model type. The lower size limit for the 1.105 model appears to be 1 µm, although more recent models can measure down to at least 0.35 µm.

Following measurement of scattering, the particles are collected on a PTFE filter, which is weighed to allow a comparison of estimated mass based on light scattering to gravimetric mass. While the estimates of mass based on light scattering are continuous, the comparison to gravimetric mass can only be made for the period over which particles have been collected on the filter. Thus "calibrations" do not allow for variations in the relationship between light scattering and mass over shorter time periods.

**Scanning Mobility Particle Sizer (SMPS)**
A number of scanning mobility particle sizers are available. One of the more common in the application for ambient air monitoring is the TSI 3936 scanning mobility particle sizer (SMPS). This method can measure the number of particles in the air, in theory between 3 and 1000 nm in diameter, but optimally between 3 and 800 nm (0.003 to 0.8 µm). It measures particle numbers based on the principal of the mobility of a charged particle in an electric field.

*"Particles entering the system are neutralized (using a radioactive source) such that they have a Fuchs equilibrium charge distribution. They then enter a Differential Mobility Analyser (DMA) where the aerosol is classified according to electrical mobility, with only particles of a narrow range of mobility exiting through the output slit. This monodisperse distribution then goes to a Condensation Particle Counter which determines the particle concentration at that size. The DMA consists of a cylinder, with a negatively charged rod at the center, the main flow through the DMA is particle free 'sheath' air. It is important that this flow is laminar. The particle flow is injected at the outside edge of the DMA, particles with a positive charge move accross the sheath flow towards the central rod, at a rate determined by their electrical mobility. Particles of a given mobility exit through the sample slit at the top of the DMA, while all other particles exit with the exhaust flow. The size of particle exiting through the slit being determined by the particles size, charge, central rod voltage, and flow within the DMA. By (in the case of the SMPS) exponentially scanning the voltage on the central rod, a full particle size distribution is built up."* (Flynn, 2005).

The sampler is portable and practical for use in ambient air monitoring programmes. The TSI 3936 SMPS has an effective particle concentration range of 20 – 10,000,000 particles per cubic centimetre.

GRIMM Technologies Incorporated also use SMPS technology in their SMPS + C sampler. This consists of an electrostatic classifier and a condensation particle counter. The method is described as follows: *"The particle stream initially passes though an impactor, which removes large particles. The particle stream then passes through an ion neutralizer, which imparts a high level of positive and negative ions and brings the particle stream to an equilibrium charge distribution. The charged and neutralized particle stream enters the electrostatic classifier, where particles are separated according to their size. The electrostatic classifier imparts a charge to the particle stream, which modifies the particle trajectory through the classifier. The degree to which particle trajectory changes is dependent on the size of the particle and the charge. For each charge range, only particles within a narrow size range have the correct trajectory to exit the classifier to the condensation particle counter. By ramping*

*the charge of the classifier from 0 to 10,000 volts DC, an entire particle size distribution is generated. The condensation particle counter measures particle concentration optically by condensing n-Butanol vapor on the small particles that are too small to count directly by optical measurement."*

**Aerodynamic Particle Sizer (APS)**

A number of aerodynamic particle size spectrometers are available that measure particle numbers. One of the more common brands used for measurements of ambient air are TSI, who have produced two models of Aerodynamic Particle Sizer (APS), the 3320 and the newer 3321. An APS can be used to make real-time measurements of the aerodynamic particle size distribution over the range of 0.5 to 32 microns. The particle size measurement is based on a particle's transit time between two laser beams that are perpendicular to an accelerating airflow. The signal processors measure each particle's transit from the time between the two pulses of scattered light that are generated as the particle passes through the two laser beams.

**Summary**

There are several monitors available that measure particle numbers. Selection of an appropriate sampler will depend on the size fraction of interest and the relative costs and effectiveness of the different methods. The SMPS samplers provide particle number counts for the smallest size of particles but depending on the size fraction of interest, other samplers such as the GRIMM 1.100 series or the APS samplers may be adequate.

**Recommendations**

- Air quality researchers carrying out monitoring in New Zealand consider the inclusion of a particle numbers in their sampling programme.
- Results from GRIMM sampling carried out in New Zealand be reported both in terms of particle number as well as estimated mass.
- Air quality researchers/ practitioners carrying out source sampling in New Zealand consider the inclusion of a particle numbers in their programmes to allow inventory type methodologies to be applied to particle numbers as well as particle mass.
- Ongoing monitoring of literature relating to the causes of health impacts and the role of particle numbers. If results are sufficient to require air quality management based on particle numbers rather than mass then additional work on options for measuring particle numbers and for conducting particle number inventories should be a priority.

## Reference for Section 3.3

Flynn, M., Scanning Mobility Particle Sizer (SMPS) - Technical Information. http://cloudbase.phy.umist.ac.uk/field/instruments/smps.htm

*Watson, J.G., and Chow, J. C., 2005, Ultrafine Particle Distributions and Concentrations at the Fresno Supersite. Keynote presentation to The 17th International Clean Air & Environment Conference Hobart, Tasmania, Australia, May 2005.*

## 3.4 Particulate Matter Component Composition and Source Apportionment

The purpose of this section is to:

- Provide an overview of existing filter-based source apportionment studies carried out in New Zealand.
- Evaluate the costs and benefits of undertaking more chemical composition source apportionment studies in New Zealand.
- Make recommendations to further improve our understanding of sources of particles in New Zealand.

The term "*filter based source apportionment studies*" is used here to describe the technique whereby the ratio of chemicals in particulate samples is used to apportion particulate mass to sources. The filters are analysed using a range of methods including Ion Beam Analysis using proton induced x-ray emissions (**PIXE)** for elements and ion chromatography for inorganic ions. The main sampling systems used in New Zealand are the Super Speciation Air Sampling System (**SuperSASS),** the Reference Ambient Air Sampler (**RAAS)** and the **Gent** samplers. Auckland Regional Council is in the process of purchasing a Partisol Speciation Sampler to replace their current RAAS system.

In New Zealand, the concentrations of different substances on the filters have been analysed for clustering using primarily Principal Components Analysis (PCA) or Positive Matrix Factorisation (PMF). This involves the identification of groups of elements (profiles) that represent different sources and the evaluation of the contribution of each profile to mass.

**Source apportionment in New Zealand**

Source apportionment studies that use the ratio of chemicals in particulate samples to apportion particulate mass to sources are relatively limited in New Zealand. Both Environment Canterbury and Greater Wellington Regional Council have completed source apportionment studies for one urban area (Christchurch and Masterton respectively). Auckland Regional Council have carried out a preliminary source apportionment study and are in the process of undertaking a comprehensive data collection programme to allow for a more thorough and detailed analysis of sources of particles for a site in Auckland.

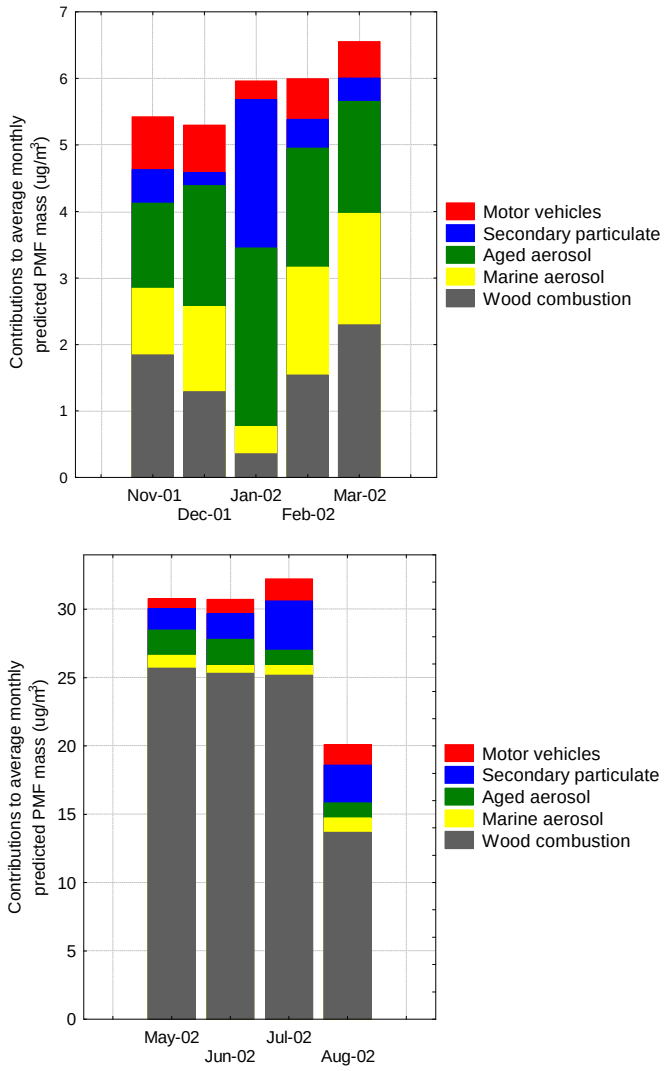
**Christchurch**

Two chemical composition source apportionment studies have been carried out in Christchurch over the past five years. In the first study source apportionment was used initially to determine sources contributing to particulate mass. The results were then used to evaluate the relative contribution of these sources to visibility degradation in the City. Because the objectives of the study related to visibility degradation, samples were not representative of 24-hour average particulate mass and therefore are not of value in assessing sources for managing $PM_{10}$ concentrations relative to the NES.

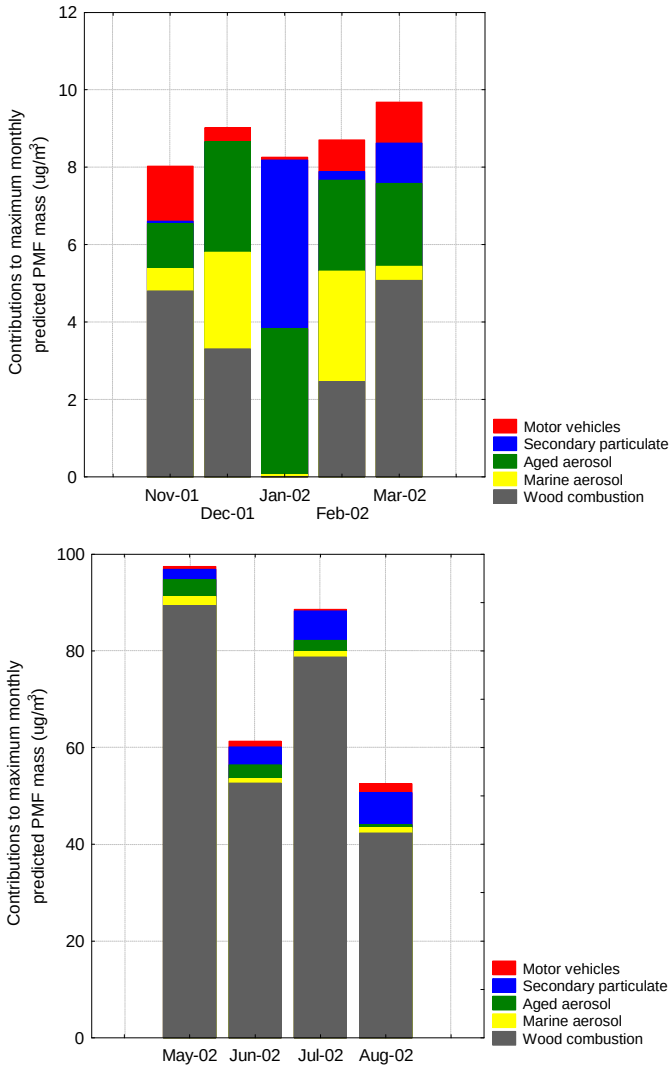
To assess sources of ambient 24-hour average particulate for the purposes of air quality management, a comprehensive source apportionment study using PMF was carried out for Christchurch during 2002 (Scott, 2005). Source profiling identified five sources of $PM_{10}$, which were classified as motor vehicles, secondary particulate, wood burning, marine aerosol and aged aerosol. The latter source included what appeared to be aged (chlorine depleted) marine aerosol that had reacted with urban sources to give sodium sulphate as well as other sources such as soil (Scott, 2005 pers comm.). Figures 3.1 and 3.2 show the relative contribution of sources to $PM_{10}$ concentrations during the summer and winter months.

Figures 3.3 and 3.4 show the relative contribution of sources to average summer and wintertime $PM_{10}$ concentrations. While the main source of $PM_{10}$ concentrations during the winter was identified as domestic home heating, around 17% of the particulate was estimated to occur from natural sources or secondary particles, neither of which are included in emission inventory assessments in New Zealand. This finding has significant implications for the management of $PM_{10}$ concentrations and highlights the importance of source apportionment type studies in providing a more comprehensive evaluation of sources of $PM_{10}$.

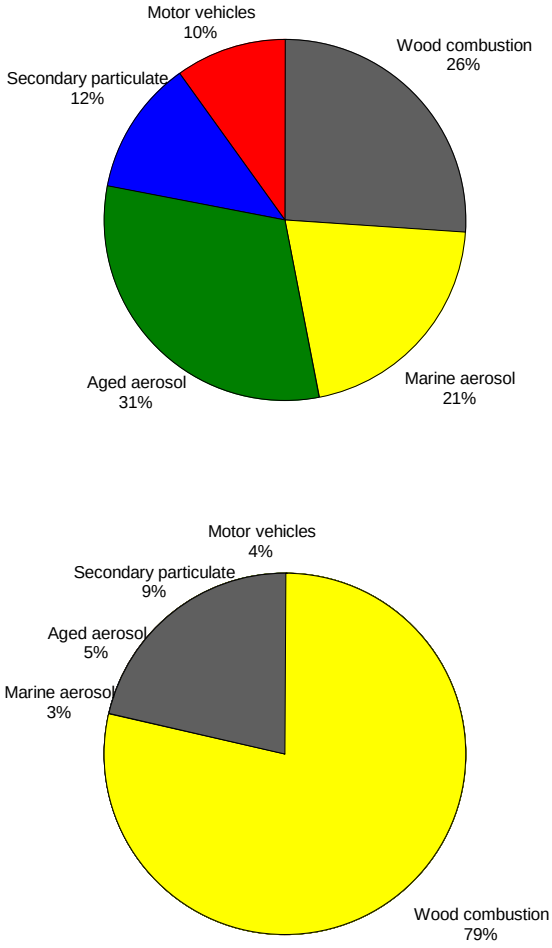
Of the natural sources in Christchurch, marine aerosol appears as the dominant contributor to $PM_{10}$ concentrations. The relative contribution of marine aerosol related sources during the wintertime is less (3% sea spray and 5% aged marine aerosol) than during the summer (21% marine aerosol and 31% aged aerosol).



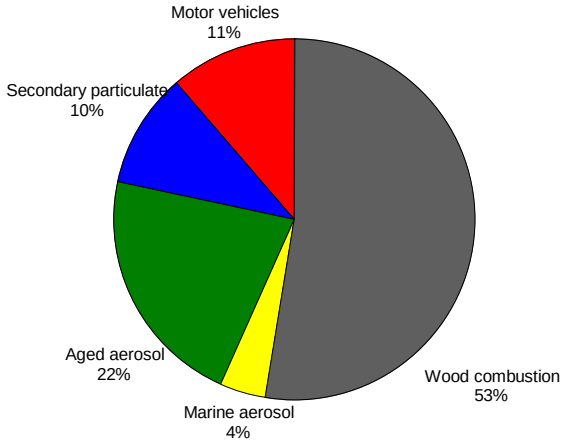

Figures 3.1 a (top) and b (bottom) Contributions to monthly average (a) summer and (b) winter PMF mass (24-hour average), Christchurch, 2001/2002 (from Scott, 2005)

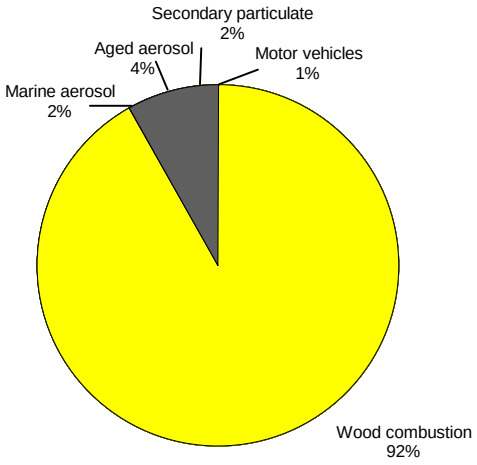



Figures 3.2 a (top) and b (bottom) Contributions to monthly maximum (a) summer and (b) winter PMF mass (24-hour average), Christchurch, 2001/2002 (from Scott, 2005)




Figures 3.3 a (top) and b (bottom) Contributions to average (a) summer and (b) winter PMF mass (24-hour average), Christchurch, 2001/2002 (from Scott, 2005)




Figures 3.4 a (top) and b (bottom) Contributions to maximum (a) summer and (b) winter PMF mass (24-hour average), Christchurch, 2001/2002 (from Scott, 2005)

**Masterton**

Davy *et al.* (2005) outline results of the Greater Wellington Regional Council study which used filter based source apportionment methods to determine the relative contribution of different sources to both $PM_{2.0}$ and $PM_{10\text{-}2.0}$ in Masterton. The samples were collected using the GENT sampling system for the period April 2002 to November 2004. Principal Components Analysis was used to determine the relative contribution of different sources to particles in the two different size fractions.

Four source profiles were identified and occurred in differing contributions in each size fraction. These were identified as soil, sea spray, biomass burning and a source labelled Ni/Cr. No analysis for sulphates or nitrates (secondary particles) was included in the study.

Results showed the main contributor to the coarse ($PM_{10\text{-}2.0}$) size fraction was sea salt but that biomass burning dominated the fine fraction, particularly during the winter months. On days when 24-hour average $PM_{10}$ concentrations exceeded the ambient air quality guideline and NES value of 50 µg $m^{-3}$, the relative contribution to $PM_{10}$ was biomass burning 92%, sea salt 6% and soil 2%.

**Auckland**

A preliminary source apportionment study was carried out in Auckland during 2001. Results suggested three groupings of concentrations of elements that consistently varied together. Based on the specific elements present

and their relative abundances, these groupings were labelled combustion, sea spray and potassium iodide. The key findings from the analysis were:

- Particulate from sea spray is most dominant in the coarser TSP and $PM_{10}$ size fractions, although measurable contributions still occur in the $PM_{2.5}$ size fraction.
- On some days the sea spray contribution to $PM_{10}$ concentrations is significant, even at the traffic dominated monitoring sites.
- The Penrose monitoring site appears to be influenced by a localised source of potassium iodide, although concentrations from this source are generally low relative to other sources.

The main issues for Auckland that may be resolved using a filter based source apportionment study are the contribution of motor vehicles versus domestic fires, spatial variations in the contribution of different sources to $PM_{10}$, and the contribution of natural (unmanageable) sources of $PM_{10}$. The relative contribution of motor vehicles versus domestic fires was not resolved using PCA on the preliminary study but may be possible based on the results of the monitoring currently being undertaken, owing to improved programme design and data collection.

The two main natural sources contributing to $PM_{10}$ concentrations in Auckland are likely to be sea spray and dusts. As indicated above, there were limitations with the design of the preliminary source apportionment study for Auckland. This restricted the subsequent PCA analysis. However, the sea salt profiling was relatively straightforward and a reasonable indication of sea spray was possible. Because of the limitations of the study, the PCA analysis did not extract a profile for dusts of any kind. A basic idea of the dust contribution may be evaluated through exploration of concentrations of specific elements. However, no quantifiable assessment of the dust contribution was possible based on the information available.

The sea salt profiling done for the PCA analysis on the preliminary filters indicated the following sea salt composition (Cl 47%, Na, 16%, S 16%, Ca 10%, K 7%, Mg 4%). An estimate of concentrations of $PM_{10}$ from sea spray was made for each location based on the average Cl concentration (Cl $\mu g\ m^{-3}$ x 1/47% = sea spray). This indicated the following contributions:

Henderson – around 5 $\mu g\ m^{-3}$
Queen Street – around 5 $\mu g\ m^{-3}$
Khyber Pass – around 4 $\mu g\ m^{-3}$

However, in this case the methodology may overestimate the sea spray contribution if other sources e.g., combustion contributes to Cl concentrations. Other limitations include the small number of sample days for which sea spray contributions have been estimated[1]. The numbers of samples in each location were 20 in Henderson 13 for Queen Street and 12 for Khyber Pass, with all samples being taken primarily during August and September 2001.

Because of urban nature of Auckland it is likely that the dust contribution will be dominated by road dust. No profile for road dust has been established for Auckland based on the preliminary study. However, should road dust be a significant contributor to particulate in Auckland, analysis of the current study should provide some indication of the contribution from this source.

**Issues for New Zealand**

Existing source apportionment studies contribute significantly to our understanding on the potential contribution of sources, particularly those not included in inventory type studies to $PM_{10}$ concentrations. They also provide insight as to potential variations with season and have implications for assessments relating to annual average $PM_{10}$ concentrations.

There have been a number of issues in New Zealand relating to the design and implementation of filter based source apportionment studies. These relate to the selection of sampling systems, filter media, analytical methods and data analysis. The preparation of a guidance document for Councils wishing to undertake filter based source apportionment studies would be particularly beneficial in minimising loss of money or data associated with poor design and implementation of these studies.

[1] The number of samples used in the PCA was higher as TSP, $PM_{10}$ and $PM_{2.5}$ filters were used to determine source profiles.

The other main issue for New Zealand is the small number of filter based source apportionment studies that have been carried out. As a result, the potential contribution of sources such as marine aerosol and dusts (including resuspended road dust) is largely unknown. While the actual contribution of these sources to $PM_{10}$ concentrations will be site specific and therefore should be investigated on a case-by case basis, more studies in a range of locations, especially likely worst-case situations, will provide some indication of likely "worst-case" scenarios. In the case of road dust contributions, relationships between variables such as tailpipe motor vehicle emissions and road dust emissions could be evaluated to determine whether a variable such as tailpipe emissions could be used to provide an indication of the likely road dust contribution.

In addition, further source apportionment studies would be of value in contributing to the current (relatively small) database of source profiles for New Zealand. Collection of additional source information to contribute to our understanding of these profiles may also be of value.

**Recommendations:**
This research programme considers investing time and/or resources into a New Zealand based source apportionment study using filter based methods. The aim of this study would be to improve information on the following issues:

- the potential contributions of in particular natural sources of particles in urban areas currently exceeding the NES
- source profiles for New Zealand, in particular differences between different types of combustion processes
- determine if relationships can be made between external variables that may allow for some proxy indications of sources

This research programme considers the preparation of a good practice guide for conducting source apportionment studies in New Zealand be prepared. This should include an evaluation of options for measuring elemental and organic carbon concentrations in New Zealand

Options, which would achieve the recommended outcomes, include:

- Collaborative Study
  - Design a collaborative programme using filter based source apportionment techniques.
  - Form a Working/Advisory Group with Stakeholders
  - Request access to the data that has been collected to date
- FRST Standalone Study
  - Design and carry out a field campaign that would provide the quality and quantity of data which would allow the desired outcomes to be achieved

**References for Section 3.4**

[1] Davy, P., Trompetter, W. J., Markwitz, A., Weatherburn, D. C., 2005, Elemental analysis and source apportionment of ambient particulate matter at Masterton, New Zealand. 2005 Biopixe conference, Wellington New Zealand 17-21 January 2005.

Scott, A., 2005, "Source apportionment and chemical characterisation of airborne fine particulate matter in Christchurch, New Zealand" draft PhD thesis, University of Canterbury – unpublished.

## 3.5 Background Concentrations of PM

The purpose of this section is to evaluate:

- Issues relating to the collection of data on natural source emissions and contributions to $PM_{10}$ concentrations.
- Existing information on $PM_{10}$ concentrations in urban areas of New Zealand that may occur as a result of emissions from natural sources.
- Provide useful recommendations relating to the collection of data on background concentrations of $PM_{10}$ in New Zealand.

The main sources of natural emissions of $PM_{10}$ in New Zealand are likely to be sea spray, pollens and wind blown dusts. The contribution of these sources will depend on a number of factors including:

- Proximity to the sea and topography of the coastline.
- Meteorology, in particular wind speed and direction.
- Land use activities in and around the urban area, including use of unsealed roadways.
- Vegetation.
- Emissions from anthropogenic sources.

**Data collection methods and existing data for New Zealand**

Some methods of estimating emissions from some natural sources have been derived overseas for emission inventory studies. In particular, the Greater Vancouver Regional District (GVRD, 1995) reports a methodology for estimating sea spray contributions. The Victorian EPA (VEPA, 2002) also specifies a method developed by the USEPA for estimating road dust and applies this to estimates of emissions for Auckland. These estimates rely of default Australia National Pollution Inventory values for silt loading data and result in estimates of road dust contribution to $PM_{10}$ that are not supported by the results of the preliminary chemical composition studies for Auckland (Wilton, 2004). Neither of the methods have been validated in the New Zealand context and based on the limited validation of methodology and required assumptions both would seem insufficiently robust to provide a reasonable estimate of contributions to $PM_{10}$ emissions in New Zealand.

Air quality monitoring has been used in some locations (for example, Baring Head) to provide an indication of "background" concentrations of $PM_{10}$. The use of these data for air quality management in other areas, i.e., as a reflection of the potential for contribution from background sources, is limited. This is because background concentrations measured in one location are unlikely to provide a reasonable indication of concentrations from the same sources in a different area owing to variations in factors such as proximity to sources, topography and meteorology.

Air quality monitoring for $PM_{10}$ mass alone is generally of little or no value in gathering information on sources contributing to measured concentrations. In particular, analyses that attempt to use hourly variations in $PM_{10}$ concentrations to attempt to quantify the contribution of different sources, without adequately controlling for meteorology, generally rely on assumptions that are not valid.

In certain circumstances, some qualitative information may be derived from the collection of $PM_{10}$ mass concentration data. In particular, peaks in $PM_{10}$ concentrations outside of the typical urban $PM_{10}$ profile may be a good indicator of atypical $PM_{10}$ sources in a particular area. One location where the daily variations in $PM_{10}$ concentrations suggest a contribution from atypical urban sources is Kaikoura.

Figure 3.5 shows 24-hour average $PM_{10}$ concentrations measured in Kaikoura during 2002 and early 2003. The monitoring method was a TEOM with a sample temperature of 40 °C. A total of seven guideline exceedences were measured during sample period (March 2002 to March 2003). Of these, three occurred during the winter months and four during the summer months.

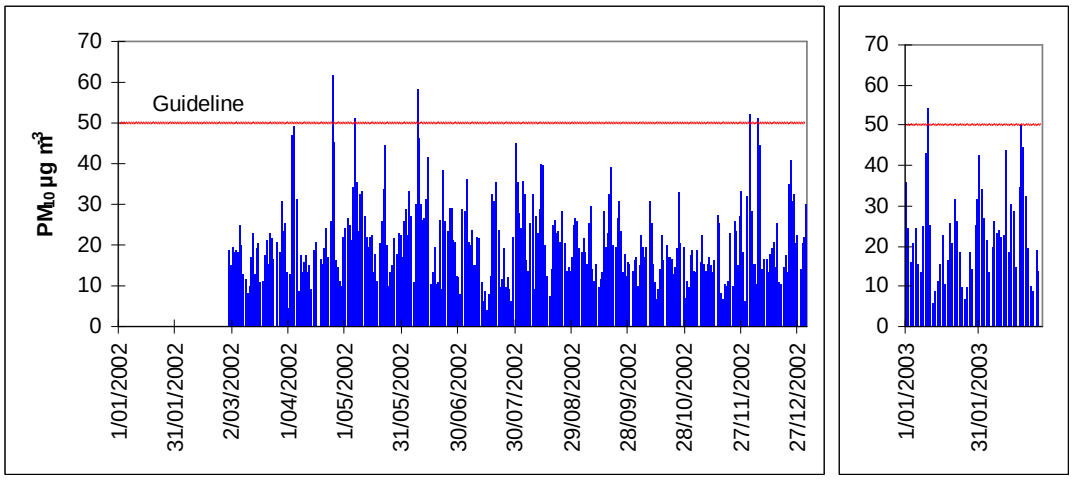



Figure 3.5: 24-hour average $PM_{10}$ concentrations measured in Kaikoura during 2002/03

Figure 3.6 shows hourly variations in concentrations of contaminants ($PM_{10}$, $PM_{2.5}$ and carbon monoxide (CO)) in Kaikoura relative to wind speed and wind direction on days when the 24 hour average $PM_{10}$ concentration was 50 µg $m^{-3}$ or more. Low concentrations of CO and the predominance of winds from the northeast, east and southeast (coastal direction) during the summer months suggests a non combustion, source of $PM_{10}$ that could be marine aerosol. If so, it appears elevated marine aerosol can occur under a range of wind speeds including wind speeds less than 2 $ms^{-1}$, although this appears to be less common than for wind speeds greater than 2 $ms^{-1}$. The analysis undertaken to date gives some indication that summertime exceedences are (at least in part) caused by marine aerosol. However further in-depth analysis is needed before the source/s of these elevated concentrations are unambiguous identified.

Causes of elevated $PM_{10}$ concentrations results in guideline exceedences during the winter months are less obvious. From the data available it would appear that a combination of combustion activities and a source of coarse particulate in the size fraction $PM_{10}$-$PM_{2.5}$. The elevated CO concentrations are an indicator that combustion processes are contributing on the 24 April, 6 May and for a shorter period during the evening of the 8 June. A separate source of coarser particles is also likely given the low ratio of $PM_{2.5}$ to $PM_{10}$ on the days when data for parameters are available (24 April and 6 May).

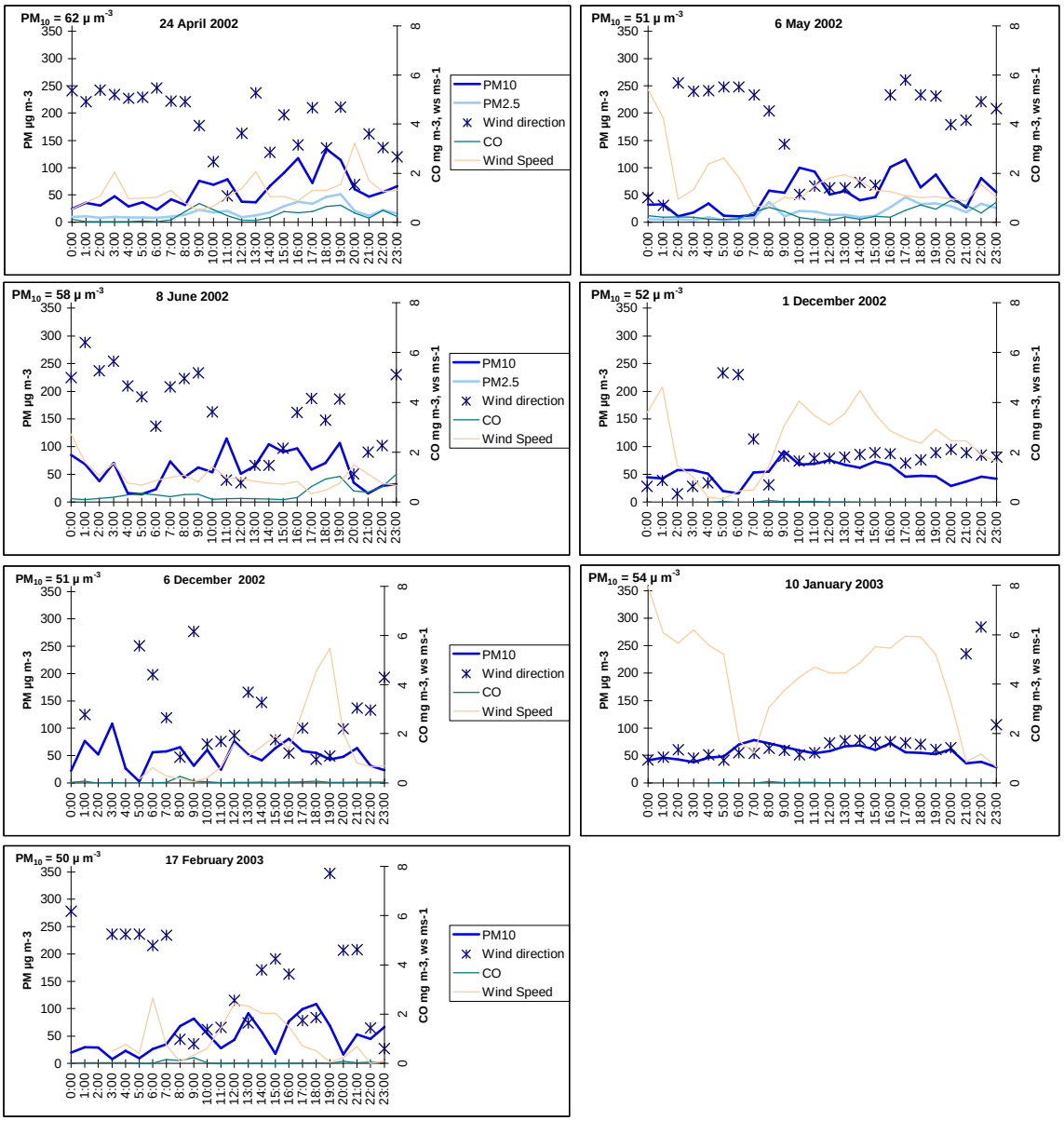



Figure 3.6: Daily variations in $PM_{10,}$ $PM_{2.5}$ and CO concentrations, wind speed and wind direction on days the 24-hour average $PM_{10}$ concentration in Kaikoura exceeded 50 µg $m^{-3}$.

These results suggest that source apportionment studies using chemical analyses of filters and statistical methods such as Principal Components Analysis (PCA) or Positive Matrix Factorisation (PMF) can provide a reliable method for estimating the contribution from natural sources to $PM_{10}$ concentrations, in some circumstances. However, these types of studies are limited in New Zealand. Section 3.5 outlines results from these types of source apportionment studies carried out in New Zealand to date, including the probable sea spray and dust contributions.

Results suggest possible sea spray and dust contributions to $PM_{10}$ concentrations are:

- Auckland - 5-6 µg $m^{-3}$ (estimated contribution to annual average $PM_{10}$ concentrations)
- Masterton **-** up to 4 µg $m^{-3}$ when $PM_{10}$ concentrations are greater than 50 µg $m^{-3}$
- Christchurch – 52% of summer and 8% of winter (2001/2002), dominated by sea spray and aged marine aerosol.

Another approach to investigating background concentrations of $PM_{10}$ is undertaking ambient air quality monitoring in non-urban areas. Monitors are located at sites that are predominately up- or down-wind of the area of interest.

ARC have installed two monitors in locations (to the north and south of the city), where anthropogenic pollutants are much less likely to contribute significantly to the total $PM_{10}$ loading. The purpose of this monitoring is to assess the concentrations of $PM_{10}$ that are entering the Auckland LAMAs from other areas. No results are available yet but the aim of this monitoring is to assess the influence of natural sources of PM10 on urban air quality.

**Recommendations:**

- The FRST programme considers implementing source apportionment studies to evaluate the contribution of natural sources to $PM_{10}$ concentrations in likely hotspots to provide an indication of likely worst-case contributions. In particular, a hotspot for sea spray contribution (e.g., Kaikoura) and a road dust hotspot (e.g., Khyber Pass Road or Queen Street).
- That the above analysis be used to provide options for the inclusion of background sources in areas where site-specific source apportionment has not been carried out and air quality management is required
- The FRST programme assess the potential use of non-urban ambient air quality monitoring to evaluate the contribution of background sources to $PM_{10}$ concentrations in urban air.

**References for Section3.5**

GVRD, 1995, Emission Inventory for the Lower Fraser Valley Airshed: Technical Appendix: Detailed Listing of Methodology and Results. Greater Vancouver Regional District.

Scott, A., 2005, "Source apportionment and chemical characterisation of airborne fine particulate matter in Christchurch, New Zealand" draft PhD thesis, University of Canterbury – unpublished.

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