National Air Quality Working Group

Research Strategy for
Air Quality Management - 2012

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Prepared for:

National Air Quality Working Group

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1 Background

The National Air Quality Working Group (NAQWG) had identified that a unified air quality research strategy was needed to ensure that researchers and funders were aware of research required at a national level to support local and central government functions in regards to air quality. The development of this process began in 2011 with the NAQWG identifying 10 research areas and some of the research needs associated with these. This information provided the basis from which this NAQWG research strategy has been developed.

Regional Councils and Unitary Authorities have responsibilities under the Resource Management Act (RMA) to manage air quality for their communities. The National Environmental Standard for Air Quality (NES-AQ) sets specific standards for several air contaminants and requires Councils to ensure these standards are met. Councils also have wider management requirements under the RMA and Local Government Act which can include a need to actively management of other contaminants not covered by the NES-AQ and the assessment of emerging or new air quality issues that may affect community health or environmental quality.

Air quality management needs vary across councils throughout New Zealand. Some areas are dominated by emissions from solid fuel burners with discharges from isolated large industries also presenting challenges, while regions with larger urban centers are also concerned with transport based emissions and significant industrial emissions. Due to this range in issues, the research needs vary across Councils and the approach taken to this strategy attempts to consider this range of needs and goes some way to addressing this variance.

The research needs for Councils are not just driven by established planning frameworks. In some cases air quality monitoring and investigations by Councils can identify more management issues which can direct further research requirements and support the need for further guideline or policy development.

In addition to the role Councils play in managing air quality, other agencies also have an interest in various aspects relating to both the quantification and management of air quality issues. These agencies include the Ministry for the Environment, Ministry of Transport, New Zealand Transport Authority (NZTA) and Ministry of Health. There are also a number of agencies (Crown Research Institutes, universities and consultancies) that are actively engaged in the research and the development of management approaches for air quality. Some of the work being undertaken by these agencies supports or is in parallel to the development of this strategy and should also be considered when developing priorities to avoid possible duplication of work and dilution of effort.

The development of this strategy has been carried out under Envirolink proposal No: 1103-HBRC162.

2 Strategy Objectives

The objectives of this strategy are to develop a guiding document for management of air quality in New Zealand that:

- provides a stocktake of recent and current research relevant to air quality management in NZ;
- provides a prioritised list of tangible research needs and outlines possible projects.

It is anticipated that having an agreed research strategy will create efficiencies and encourage more collaborative work between councils and with research agencies. It may also encourage pooling of resources and joint approaches to research requests, all of which should lead to improved efficiencies and outcomes from the resources available.

It is anticipated that the strategy will provide a clear picture of Council research needs and their relative priority. This should assist researchers (including CRI's, universities and consultants) and funding agencies (MSI, Envirolink) with targeting research work towards what is important to local and central government in managing air quality. This will in turn help to improve the value and uptake of the work generated by these agencies. Members of the NAQWG will use the strategy internally to guide their organisation's air quality management programmes and allocation of research resources.

The structure and content of the strategy follow the main components outlined in Figure 1. This diagram outlines the logic that has been used in the development of this strategy. This logic aims to provide a sound analysis of the priorities for research based on known research gaps for effective management of air quality in New Zealand.
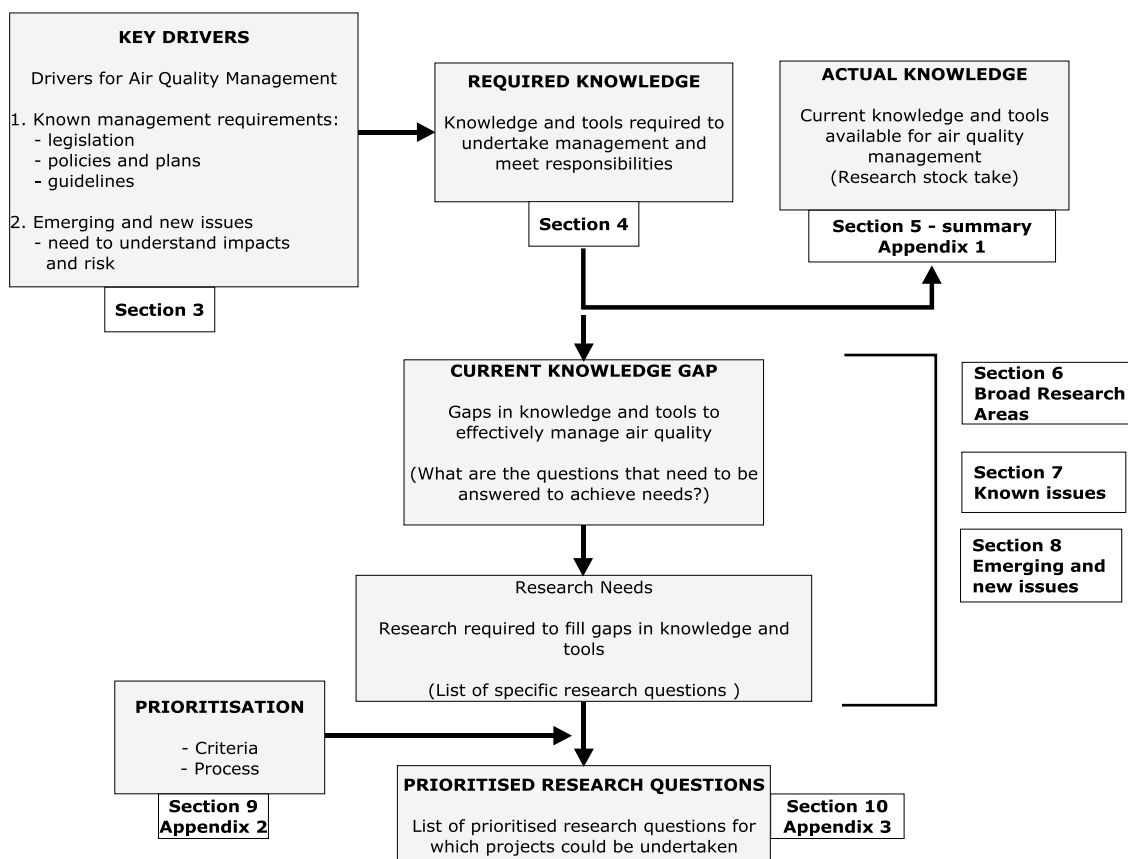
Figure 1: Process logic for identifying and prioritising air quality research

The steps taken to develop this strategy were as follows:
1. Develop the scope of work with the project team.
2. Define key management needs and knowledge requirements (refer Section 4.3, Table 3)
3. Establishment of broad research areas based on the original 10 identified areas and which were seen to collectively cover the range of key management needs. These were put into the pressure/state/response framework (Table 5)
4. Provide a stocktake of New Zealand research on air quality and it's management (Appendix 1).

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5. A limited gap analysis using expert input from the project team and their knowledge of the current information requirements and stocktake material (a thorough gap analysis was difficult to undertake given the volume of information collected).
6. Development of a set of key research questions that linked to the broad research areas and incorporated previous work by NAQWG.
7. Circulation of the broad research areas and specific research questions to all member Councils of NAQWG who were asked to run them through the prioritisation process based on their requirements (Section 9)
8. Development of prioritised listing of research areas and specific questions based on Regional Council feedback (Section 10).
9. A summary of the results and findings from the process are provided and recommendations are made.

Scope of Research

Many definitions of "research" can be applied within a group such as NAQWG. For this strategy a definition of research across a spectrum has been defined and used (Figure 2).

The spectrum contains three key areas which are defined below:
1. Information and data collection, although not strictly "research" is considered a precursor and necessary element for undertaking more applied or pure research activities. The inclusion of these parameters recognises that monitoring and collection of data about state and pressure is important to support this research strategy.
2. Applied research is seen as primarily being focused on understanding and creating management responses to known management requirements and emerging management needs.
3. Pure research is primarily used to further understand emerging issues and to investigate the risks and physiochemical processes associated with new management issues.

This research strategy focuses primarily on the central part of this spectrum – applied research.
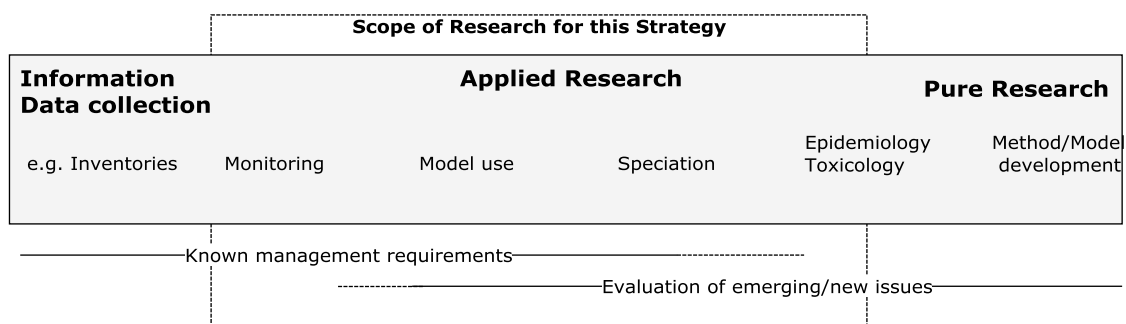
Figure 2: Research spectrum

Links to other Strategies/Investigations

There are a number of other work streams for air quality management that are being undertaken by agencies other than regional councils who are involved in air quality. This strategy is not intended to amalgamate or duplicate these activities. An awareness of other research agendas and assessments of key management needs are seen as supportive of this strategy and should be considered in conjunction with this document. Key examples of relevant work are:
- Stocktake of Transport Related Air Pollution (TRAP) Research in New Zealand – New Zealand Transport Agency (Kuschel and Bluett, 2010)

- Regional Land Transport Strategies (e.g. Auckland Regional Land Transport Strategy 2010-2040)
- A review of particulate matter research in New Zealand: Where are we and where should we go from here – Geological and Nuclear Sciences (Ancelet, T et. al. 2012)
- Air Quality Monitoring Programme - A report prepared for the Ministry for the Environment by BECA (Beca, 2012)
- Roadmap for air quality research – NIWA. Being developed based on a series of related workshops in mid-2012.

3 Management of Air Quality in NZ

Management of air quality in New Zealand is undertaken to protect communities and the environment from the adverse effects of air pollution. The primary focus is on the impacts of air contaminants on human health. Minimising these impacts can require the management of one or more significant pollutant sources. These sources are primarily the emissions from wood burners for domestic heating, transport emissions and discharges from industrial sources. Other aspects of air quality management include protecting amenity values (nuisance odours, dust) and environmental values (spray drift, contaminant build up).

3.1 Legislation

The management requirements for air quality are primarily outlined under the Resource Management Act (1991) and implemented through National Environmental Standards for Air Quality (NES-AQ) and regional planning (Regional Policy Statements and Regional Plan Rules). The implications for air quality are also considered under the Land Transport Management Act and associated Land Transport Strategies.

Air Quality management under the RMA

Regional councils have responsibilities under the RMA and give effect to the Act through regional policies and plans. The RMA is the primary legislation that guides regional and district councils in the management of air quality work. Specifically:

- Section 5 of the RMA states that local authorities have a responsibility to sustainably manage natural and physical resources while "safeguarding the life-supporting capacity of air, water, soil and ecosystems".
- Section 30 outlines the functions that regional councils must undertake to give effect to the RMA. This includes the "control of discharges of contaminants into …air" (Section 30(f)).
- Section 15 further outlines discharges to air:.
  - Section 15(1) means that any discharge of a contaminant into air from any industrial or trade premises is allowed only if it is expressly allowed by a rule in a regional plan, a resource consent or by regulations.
  - Under Section 15(2) the opposite presumption applies to discharges of contaminants into air from any other source: that is, discharges of contaminants into air from sources other than industrial or trade premises can take place without a resource consent from the regional council if it does not contravene a regional rule or a national environmental standard. Therefore, without this plan, discharges of contaminants into air from industrial or trade premises, no matter how minor, require resource consents, while possibly significant discharges from other sources do not. A key function of a regional plan therefore will be to allow minor discharges into air from industrial and trade premises that are unlikely to have any

significant adverse effects, and to regulate other discharges that may have significant adverse effects.

- Air quality can also be affected by the use of land and by discharges of contaminants into air or onto land from that use. Section 31 of the RMA assigns the role of controlling any actual or potential effects of land use on the environment (including air) to Territorial Authorities. District plans may therefore contain provisions regulating land use to manage air quality. Such provisions must not be inconsistent with the regional plan.

Air Quality Management under the Land Transport Management Act

The Land Transport Management Act 2003 and the New Zealand Transport Strategy (NZTS) set the framework for the use, development and funding of land transport in New Zealand.

The NZTS sets out the Government's vision for transport. It is a statement on the approach the Government will take to transport, both now and in the future. The NZTS guides policy decisions about transport, and it is reflected in the activities of all government agencies that have responsibilities for, or an interest in, transport.

The NZTS is implemented through policy development, rules and legislation such as the Land Transport Management Act 2003 (LTMA). The purpose of the LTMA is to contribute to the aim of achieving an integrated, safe, responsive and sustainable land transport system. This includes objectives to protect and promote public health and ensure environmental sustainability and as such require involvement in air quality management.

Air Quality Management under the Health Act

Air quality in regards to health was originally administered by the former Department of Health under Part 5 – Air Pollution of the Health Act (1956). This part of the Health Act was repealed in 1974 by the Clean Air Act (1972). The Clean Air Act 1972, formerly the Department of Health's responsibility, was repealed in 1991 when the Resource Management Act 1991 (RMA) was promulgated.

Although the Health Act does not now deal directly with air quality, section 23 of the Health Act 1956 imposes a duty on each territorial authority to improve, promote, and protect public health within its district. The air quality issues to be managed are those within a territorial authority's district. For example in built-up areas, rubbish fires can result in frequent complaints when they are carried out in a manner, or at a frequency, that can be injurious to health or offensive.

As a means of achieving air quality objectives set out in a regional or district plan, territorial authorities can apply the nuisance provisions (section 29)[1] of the Health Act 1956 to control minor nuisance or neighbour-to-neighbour effects such as domestic fires if they are carried out in a manner, or at a frequency, which may be injurious to health or offensive. Under these nuisance provisions, territorial authorities would continue to deal with those minor discharges into air not covered by controls (e.g. rules) in a plan or where section 20A of the RMA does not apply or where no resource consent has been granted, for example, discharges into air from home heating or other domestic sources. Hence, depending on the interpretation of district, territorial authorities have duties pursuant to the Health Act to monitor air quality, report on public health risks and take such action as is necessary to abate or remove identified public health risks. The Ministry of Health has overarching obligations in this respect and must step in where a territorial authority breaches its duties.

3.2 Agencies Involved in Air Quality management

The effective management of air quality requires an integrated approach involving planning and development of broader solutions to achieve improvements in air quality. These solutions can include multiple levels and facets of government agencies with broad ranging mandates including transport, health, energy efficiency, building, industry and others. The achievement of integrated responses across agencies is challenging.

The primary agencies involved in air quality management are:
- Regional Councils
- Ministry for the Environment
- Ministry of Transport and New Zealand Transport Agency (NZTA)

Regional Councils
Regional councils have responsibility under the RMA to implement national policy statements or environmental standards that may be developed by MfE, such as the NES-AQ and to develop and implement policies that meet the requirements of the RMA and councils' communities expectations.

There is a need for councils to undertake research to assist achieving their responsibilities under S35 of the RMA which requires them to undertake monitoring and to set policy. S32 of the RMA also requires councils to understand and assess the cost/benefit of future policies.

Regional Councils also have responsibility for land transport under the LTMA. Each Regional Council is required to prepare a land transport strategy for its region. The LTMA requires regional land transport strategies to contribute to an integrated, safe, responsive and sustainable land transport system. Regional land transport strategies are likely to include objectives and policies that are relevant to the assessment of discharges to air from transport.

For example, the Environment Canterbury Regional Land Transport Strategy 2005–2015 includes the policy:
Ensure adverse environmental impacts from transport are monitored and national and regional standards are met.

One of the methods for achieving this policy is to *"implement traffic management measures that reduce pollutant levels in areas where these are close to, or exceed, national and regional environmental standards/guidelines"*.

Ministry for the Environment
The Ministry for the Environment has a role under the RMA to both develop specific regulation where required and to provide guidance to assist both regulatory and non-regulatory implementation of policy by central, regional and district/city councils.

The NES-AQ are technical environmental regulations prepared in accordance with sections 43 and 44 of the RMA. They are designed to protect public health and the environment in New Zealand by setting concentration limits that provide a set level of protection and regulating or prohibiting certain activities that pollute the air.

MfE has developed a range of good practice guides (GPG) to assist both industry and Regional Councils in undertaking their roles and responsibilities (Figure 3).
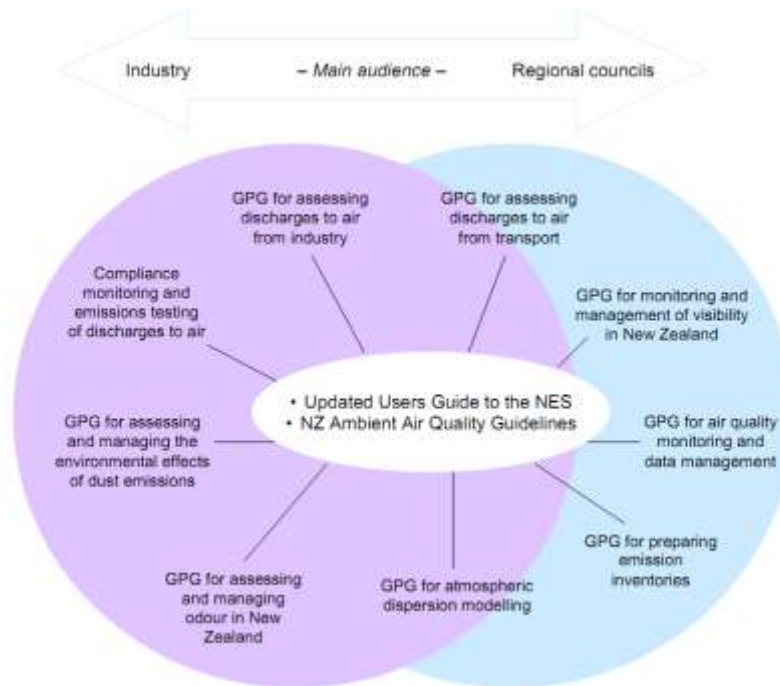
Figure 3: Range of guidance documents provided by MfE to assist industry and Regional Councils (After MfE, 2008)

Ministry of Transport/NZTA
The Ministry of Transport is responsible for government policy on transport and the NZTA is the implementation agency for these policies.

The primary document for land transport decision-makers is the Government Policy Statement which is issued by the Minister of Transport every three years and provides a ten year policy view. The Land Transport Management Act 2003 requires the Government Policy Statement (GPS - came into force on 1 July 2012) to contribute to the aim of achieving an affordable, integrated, safe, responsive and sustainable land transport system, and also to each of the following:

- assist economic development
- assist safety and personal security
- improve access and mobility
- protect and promote public health
- ensure environmental sustainability.

Managing the air quality impacts of transport projects is an important aspect of protecting and promoting public health and ensuring environmental sustainability.

The objective of NZTA is to operate the state highway system in a way that contributes to an integrated, safe, responsive, and sustainable land transport system.

In meeting this objective, these agencies are also required to "exhibit a sense of social and environmental responsibility" which includes "avoiding, to the extent reasonable in the circumstances, adverse effects on the environment".

The Land Transport Management Act also requires road-controlling authorities to take into account the GPSobjectives in preparing their land transport programme.

In addition to requirements to consider safe and sustainable regional land transport strategies and national objectives to protect and promote public health, territorial authorities and/or requiring authorities must now consider the national environmental standards for air quality when granting new designations and land-use consents.

Other Agencies
Other agencies involved in air quality management are:
- Ministryof Health
- Environmental Protection Agency (EPA)
- Energy Efficiency and Conservation Authority (EECA)

Currently the Ministry of Health's involvement in air quality management is primarily via public health units of District Health Boards at a regional level on specific management issues. The Ministry also provides an overall health management perspective, including emerging management issues (i.e. Legionnaires disease). The Ministry also has its' own research strategy which also, where appropriate, supports specific health related air quality issues e.g. PM_{10} and Christchurch liquefaction silt (2012)
Other government agencies such as EPA and EECA are primarily involved in implementation and have a role in promoting good air quality outcomes under the existing regulatory and non-regulatory frameworks.

The primary research providers in New Zealand for air quality are:
- National Institute of Water and Atmospheric Research
- GNS Sciences
- University of Canterbury
- University of Auckland
- Landcare Research
- Private Consultants such as: Emission Impossible, Environet Ltd, Golders and others

The linkages between national and regional agencies and the guiding legislation are illustrated in Figure 4.
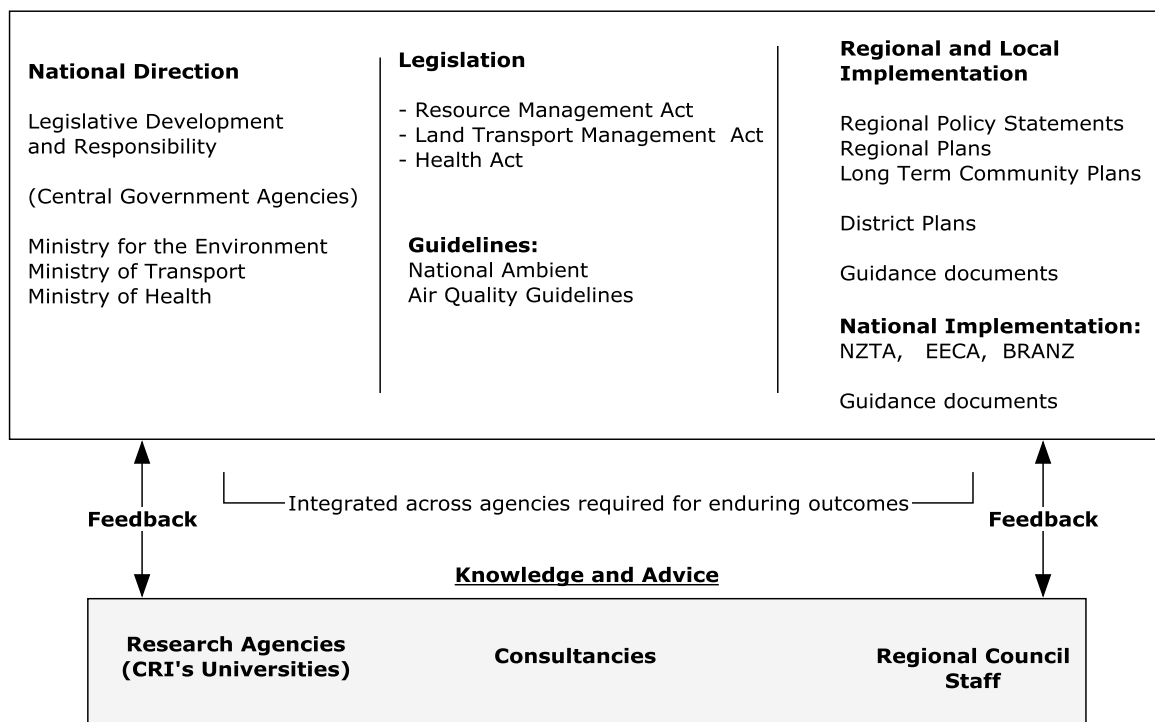
Figure 4: Linkages between national and regional agencies

3.3 Management Activities

For use in this strategy, management activities and drivers are divided into two areas:

(1) The management of "known issues" – these issues are generally defined in legislation, plans, policies or guidelines which creates a consistent national obligation to address the specific air quality issue;

(2) Understanding and preparing for the management of "emerging or new" air quality issues

The main differences between the two types of management areas are defined further in Table 1.There can be some overlap between these two areas when comparing management issues across the different Councils (e.g. $PM_{2.5}$ is treated as an emerging issue in the is strategy yet it features in Auckland's Regional Plan).

Table 1: Relative status and understanding of known management requirements and emerging or new issues

	Known Management Requirements	Emerging/New Issue Requirements
IMPACT	Impacts on human health or environment are understood enough to be considered high risk or significant (e.g. there are existing New Zealand standards or guidelines to assist management)	Impacts of the issues are not well understood or defined in New Zealand Or impact is being defined (here or overseas) but currently not considered significant or high risk to require action
STATE OF KNOWLEDGE	In many cases the state of air quality for the issues is defined and understanding of spatial variability is improving over time.	There can be limited knowledge of the state of air quality with respect to the issues.
STATE OF KNOWLEDGE	Drivers and resulting pressure are understood at a conceptual level – local assessment may still be required	For new issues drivers and resulting pressure are not well understood. For emerging issues, knowledge of drivers and pressures can be limited or is not New Zealand specific
MANA	Required management of issue is defined in legislation, policies, plans or	Active management of issue(s) not currently required. Although findings on impacts, state, drivers and pressure can

	Known Management Requirements	Emerging/New Issue Requirements
	guidelines	be feed into legislation and guidelines in future.
	Responses are being planned and implemented – although ability to respond may be hampered by scale of issue and site specific knowledge or effectiveness/benefit of different responses.	No general local management response required or guidance provided. Although the issue may be actively being pursued by one or more Region. Issue may be currently actively managed overseas.

This distinction of issues is used for this strategy as it enables different assessment criteria to be applied to each area when prioritising research needs, otherwise there is a tendency for known issues to dominate because they are the focus of Councils' day to day activities and resources.

Management of known issues is driven by:
1. Resource Management Act (1991) which requires the implementation of
    a. National Environmental Standard for Air Quality
    b. Regional Policy Statements and Regional Plans
    c. Integrated planning for mitigation or avoidance of air quality risks through both statutory and non-statutory approaches.

    d. Monitoring and reporting of air quality can confirm if targets are
    e. being met and if the rules implemented are producing the anticipated results

2. Other key legislation that cover aspects of air quality management namely:
    a. Local Government Act – (Long Term Plans)
    b. Land Transport Management Act
    c. Health Act

3. Guidelines and Standards
    a. Ambient Air Quality Guidelines

Responses to these guidelines and legislation require implementation of rules and guidelines

The identification and understanding of emerging or new issues arises from a number of sources which include:
1. Research outcomes – health studies (toxicology, epidemiology), environmental impacts, health impact/risk assessment
2. World Health Organization (WHO) standards/directives
3. European Union (EU) directives
4. United States Environmental Protection Authority (USEPA)

These sources provide guidance to developing responses that may currently not be legislated and provide direction for councils to further develop investigations and to meet their needs under RMA Section 35 and Section 32.

Outcomes from investigations and research into emerging and new issues can lead to changes within New Zealand legislation and guidelines. Once identified, quantified and legislated, these emerging and new issues become known issues for which management requirements which require implementation.

4 Management Needs and Knowledge Requirements

4.1 The Range of Air Quality Contaminants

The contaminants that need to be managed for air quality can vary between the NES-AQ, Ambient Air Quality Guidelines and those considered important as emerging or new issues. The contaminants listed in RMA Regional Policy are generally those listed in the NES-AQ and Ambient Air Quality Guidelines and are considered as known management issues. Some Council policies also include other contaminants that they consider important for their specific needs (e.g. Auckland Regional Plan for Air Quality sets targets for $PM_{2.5}$)[1].

It should be noted that research questions can be specific to one or more of these contaminants and that Regions can differ in their specific focus and relative importance of issues and contaminants. Although New Zealand standards have a lot of commonality with overseas standards there are a number of contaminants that are identified overseas but are not in New Zealand's standards (Table 2). These could be considered as emerging or new issues for New Zealand air quality management. Previously some of these contaminants were specifically excluded as they were not considered to be of concern in New Zealand. Reassessment of these may be required in the light of further monitoring and knowledge.

Table 2: Key air quality contaminants that require management based on NES-AQ, ambient air quality guidelines or are emerging management issues as they are currently actively managed overseas (after Beca, 2012)

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[1] Note: A definition distinction for known management needs and emerging issues is given in Section 3.3

Pollutant	NZ[4]	WHO (AQG 2005)	UK/EU	USA	Australia
PM_{10}	X	X	X	X	X
$PM_{2.5}$		X	X	X	X^1
SO_2	X	X	X	X	X
NO_2	X	X	X	X	X
O_3	X	X	X	X	X
CO	X	X	X	X	X
Benzene	(X^4)		X		X
1,3 Butadiene	(X)		X^2		
BaP (PAH)	(X)		X		X^3
Formaldehyde	(X)		X		X^3
Acetaldehyde	(X)				
Xylene					X^3
Toluene					X^3
Lead	(X)		X	X	X^3
Arsenic	(X)		X		
Cadmium			X		
Nickel			X		
Mercury	(X)		X		
Chromium VI	(X)				
Mercury	(X)				
Hydrogen sulphide	(X)				
Arsine	(X)				

1. NEPM advisory reporting standard
2. Only defined in terms of a UK ambient air quality objective
3. The NEPM for air toxics only specify a national monitoring and reporting obligation
4. NESAQ are denoted by X, AAQG are denoted by (X)

4.2 Overview of Management Needs

The management needs for air quality management are driven by the range of activities required under the roles and responsibilities of the management agencies (Section 3.2.& 3.3). The main management needs and knowledge requirements for air quality, identified and reviewed by the project team, are outlined in Table 3. They cover both the known needs required under the RMA and NES-AQ and other management needs that are driven by other requirements that Councils may have.

These management needs are used in Section 6 to provide context to specific research questions and to assist the prioritisation process (Figure 1).

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Table 3: Management needs and knowledge requirements for key air quality drivers

Management of Known Issues		
Regulatory requirement	**Management Need**	**Knowledge Requirement**
RMA: National Environmental Standard for Air Quality	- To know the state of PM_{10}, CO, NO_2, SO_2 and Ozone in air sheds - Understand drivers and pressures in an air shed which can create changes in the concentration of these contaminants over time and space within an airshed - Create policy and undertake implementation - Plans to ensure target values for these contaminants are met	Describing & measuring air quality: • Spatial variability and representativeness of monitoring • National consistency of measurement and QA Relationship between emissions and air quality: • Emission factors and uncertainty • Dispersion models & meteorology • Impact of chemistry and atmospheric processes • Relative source contributions (inc. natural) Managing air quality • Tracking progress & effectiveness of interventions and policy • Scenario assessment (incl. airshed models) • Technological solutions (emissions control) • Broader solutions (inter-relationships energy/housing/climate change) • Influencing human behaviour & understanding barriers to change

Management of Known Issues

Regulatory requirement	Management Need	Knowledge Requirement

RMA: Regional Policy Statements and Plans	- Can define requirements in addition to NES-AQ - management of emissions within the Region or air sheds including
	  o Particulates
	  o Products of combustion
	  o Odour
	  o Discharges of chemicals (industry and agrichemicals)
	  o Discharges of biological contaminants i.e. bioaersols
	- Policies developed and implemented to ensure that standards and adopted guideline values are met
	- Maintaining or improving air quality
	- Adverse effects of industrial/ agrichemical discharges are avoided, remedied or mitigated
	- Identify and manage localised effects – outdoor burning, odour
	- Understand and manage cumulative effects
		Quantifying and understanding air quality effects:
		• Amenity (dust and odour)
		• Human health (hydrogen sulphide)
		• Impacts of land-use on air quality (eg, agrichemicals)
		
		Relationship between emissions and air quality:
		• Emission factors and uncertainty
		• Dispersion models & meteorology
		
		Managing air quality
		• Tracking progress & effectiveness of interventions and policy
		• Scenario assessment (incl. airshed models) for cumulative effects
		• Influencing human behaviour & understanding barriers to change

Other Legislative Requirements:	- Local Government Act - Long term plans to achieve integrated planning and healthy communities - NZ Transport Management Act - Health Act	Community expectations for air quality Understanding barriers to behaviour change and role of incentives
Ambient Air Quality Guidelines	- Where not already covered by NES-AQ and Regional Policy requirements there is a need to understand and manage other guideline contaminants if required.	Describing & measuring air quality: • Fill information gaps re HAPs (eg, BaP, As, PAH) • Affordable measurement methods for HAPs

Understanding emerging and new Issues

Need	Management Need	Knowledge Requirement
RMA S5 purpose "Safeguarding the life	- Implementing new standards or guidelines (e.g. $PM_{2.5}$, annual guidelines) at national or regional level	Describing & measuring air quality: • Fill information gaps for new standards or guidelines

| supporting capacity of air,...." | - Effects of multiple pollutants and cumulative effects
- Change in focus from concentration exceedance to exposure | • Speciation of PM
• Emerging contaminants of interest (e.g. Ultrafine particles, nanoparticles, hazardous air pollutants, bioaerosols)
Quantifying and understanding air quality effects:
• Human health (incl. natural sources, HAPs and $PM_{2.5}$, and other emerging contaminants e.g. bioaerosols containing pathogens)
• Estimating exposure
• Social justice
Managing air quality:
• Influencing human behaviour & understanding barriers to change
• Multi-pollutant management
• Accountability |
| Local Government Act | | Community expectations for air quality |

Current Knowledge Stocktake

A stocktake on air quality research has been undertaken as part of the formation of this Strategy. This compilation formed a basis on which an assessment of the research gaps could be made between the management needs and knowledge requirements identified in Table 3 and the available knowledge. This gap assessment proved difficult to undertake effectively given both the volume of material collated in the stocktake and the limited awareness and understanding of relevance of this material by project team and other council staff.

5.1 Structure used for Stocktake and Research Questions

To provide a structure to the Research Stocktake the research outputs have been categorised as to whether they contribute to the knowledge about the **Pressures** and associated **Drivers** for air quality, help to define the **State** of the air resource and understanding the **Impacts**, or inform the development and assessment of management **Responses**. This follows the DPSIR framework (
Figure 5). For air quality, there is considerable overlap in publications assessing Pressure and Drivers, as well as State and Impact. Because of these overlaps only Pressure, State/Impact and Response tabs have been used to catergorise outputs in Appendix 1.
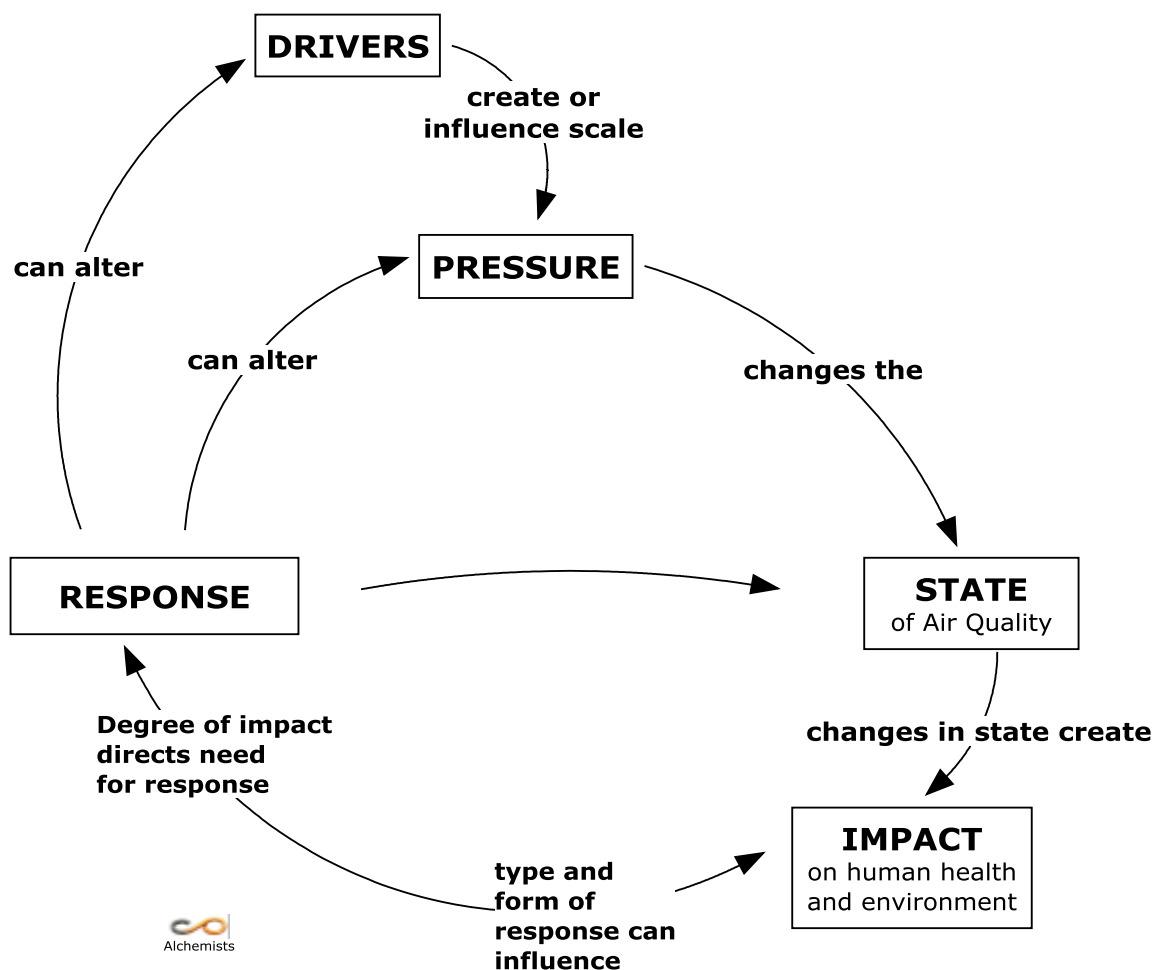
Figure 5: Drivers/Pressure State/Impact Response Framework (after MfE, 2007)

Definition of Categories
The following definition for categories have been used in the stocktake (Appendix 1):

Pressure and associated drivers
- What is causing the current state?
- Where do contaminants come from?
- Type and concentration of contaminants from different sources.
- Spatial and temporal variation in these pressures.
- What are key drivers that create the pressure?

State and its Impact
- Standard ways to define what is currently known about the resource.
- Quantifying the type and concentration of contaminants.
- Defining the spatial and temporal variability of State.
- Understanding what background/base levels are
- Tools or case studies to define state
- Health risks associated with different states

Response
Response is divided into two areas:

Management of State and Risk – Planning and Implementation
- What management responses are possible/best to manage the state, drivers and associated risks (e.g: rules, campaigns, changing standards)
- How efficient are different response options?
- What are social and behavioral drivers/barriers to change?

Effectiveness of Management Responses – Review
- How effective are the management responses being undertaken and any recommendations for improvement?
- How effective have approaches been at achieving the outcome needed – how much progress towards the outcome has been made

In addition to these categories two other categories have been included in the stocktake:

- Standards - Documents that provide guidance, standards and other framework information and criteria.

- Proceedings and other - Information on papers and abstracts at various conferences. This list is added for information purposes as these references were found while undertaking the stocktake. No electronic links are provided.

The references from the stocktake are provided in Appendix 1. The original stocktake file which contains key words and electronic links is available as an Excel spreadsheet.

The stocktake has been confined by the following parameters:

- Research which is specific to New Zealand and has primarily been conducted within New Zealand
- Information compiled and/or published after 2000 however the majority of information that has been sourced is post 2005 for currency.
- Information with a research/management focus excluding emissions inventories specific to various areas. It was considered that these are generally undertaken using a standard format that all councils are familiar with and there was minimal benefit to be gained from compiling a list of all of this work. They have been

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included if they have additional areas of information which go beyond the scope of standard inventories.

- A hierarchical system has been used when dealing with multiple forms of one piece of information to avoid duplication (ie: report, journal papers and conference proceedings). If a report is available this is what is referenced and nothing else; if no report is available yet a paper has been published this is referenced and nothing else; if no report or paper exists and there is a conference proceeding then this has been included.

Sources which have been accessed:

- Members of the NAQWG have been asked to provide references and links to those documents which are relevant for this compilation
- Discussion have been had with relevant research agencies and attempts have been made to access relevant information and reports
- Lists of publications from key academic staff have been utilised and online journals have been accessed where possible
- A general search of Regional Council and Unitary authority websites has been undertaken
- Identified journal articles have been accessed on line where possible

Where possible, reports and articles have been accessed and a synopsis of the information provided. If the information has been provided in an electronic form then the relevant link to a website has been included when available (included in electronic spreadsheet).

Limitations:

Some articles and reports in the stocktake do not include a synopsis of the work covered. This is primarily due to being unable to access the report and/or journal or proceedings to correctly identify the true and full nature of the work undertaken. These articles and reports have still been provided in the stocktake for completeness but without a summary synopsis

Relevance of stocktake material:

It was difficult to determine the relevance of the wide range of material found during the stocktake due to the large amount of material gathered, difficulty in accessing detailed information about some of this material, and a limited awareness of material identified by staff involved in air quality management.

The documents in the stocktake are represented by a relatively even spread between published papers, reports for FRST (now MSI) or other agencies/clients, and reports commissioned by Councils (Table 4). Although, there is a tendency for published papers to be more prevalent in the 'pressure' area and council report in 'response' areas. It should also be noted that many of the published papers are based on work that related to work undertaken for or supported by Councils.

A process was undertaken to get an indicative assessment of the relevance of the stocktake material. This was done by asking council air quality staff, including the project team. They were asked to quickly rank the relevance of the references obtained based on firstly whether they had not seen them and if they had then applying a simply High, Medium, Low ranking. Feedback was received from only 6 of the 16 councils and this has been used to provide a general indication of relevance and is shown in Appendix 1. The rankings used are Gold – highest third ranked, Silver – middle third ranked, Bronze – lowest third ranked. White indicates reference – not seen by all of those who provided rankings (Appendix 1).

Based on the feedback from council staff the awareness of the material collated in the stocktake is low (Table 4) with 60-87% of the material having not been seen by those who responded.

Doc. Type	Pressure related docs.	State related docs.	Reponses related docs.
Published Papers	34	26	13
Reports – FRST/client	23	18	20
Council Reports	26	22	33
Theses	2		
% unseen by respondents	60%	87%	80%

Of the 'Proceedings and other miscellaneous information' 80% of them were unseen by respondents to the ranking. For the collated 'Standards' in the stocktake only 24% were unseen by respondents. It is assumed that this level of awareness is representative of all council staff.

This lack of awareness of the material in the stocktake has meant that undertaking a thorough gap analysis against the management needs as proposed in the strategy process (Figure 1) was not possible. Therefore the assessment of knowledge gaps and research questions has been primarily based on previous investigations undertaken by the NAQWG and further expert input during the process from the project team.

6 Research Areas and Questions

This section contains the identified broad research areas and key research questions for known management needs and emerging/new issues as they relate to the broad research areas.

This section is also structured to the Pressure-State-Response framework as outlined in Section 5.1.

6.1 Broad Research Areas

During the development of the strategy it became clear that it would be helpful to maintain some definition of the broad areas of air quality research. The NAQWG had previously identified 10 priority areas. These were reviewed and structured into a broad set of research areas under the Pressure-State-Response framework (Table 5).

These broad groupings were then used in the development process to structure the key research questions and were provided to council staff to undertake a high level prioritisation (see Section 8.1).

Table 5: Broad research areas for air quality management.

Management Domain	Broad level research area
Pressure Understanding relationships between emissions and air quality	Understanding anthropogenic contributions (emission factors and uncertainty)
	Use of dispersion models & meteorological information in defining pressure
	Understanding the impacts of chemistry and atmospheric processes (inc. secondary particles) on pressures
	Source apportionment (inc. natural sources)
State Describing & measuring air quality	Quantifying spatial variability of air quality
	Information gaps regarding air toxics
	Creating affordable monitoring methods
	Ensuring quality measurement of Air Quality (national consistency & QA & representativeness)
Impact of the State Quantifying effects of air quality	Understanding human health effects of exposure to different air quality states (inc. natural sources & air toxics)
	Understanding variability of social susceptibility/consequences of poor air quality on population health
	Methods for exposure assessment and management
Response- to "Pressure-State" Managing (response) the pressures (emissions) to improve the state (ambient air quality)	Tools and methods for creating scenario assessment to inform responses
	How to effectively apply dispersion modelling to define management responses
	How to effectively influence human behaviour & understanding barriers to change
	Understanding multi-pollutant management to create integrated responses

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Management Domain	Broad level research area
	Identifying or creating technological solutions to improve air quality
	Methods or tools to create broader solutions (inter-relationships between energy/housing/climate change)
Response effect on "Impact" Are responses actually reducing pressures (emissions). Is reduced pressure improving state and is health (impact) improving as a consequence?	Understanding and quantifying the effectiveness of management responses

6.2 Knowledge Gaps for Known Management Requirements

The following are key research questions identified for known management requirements (Table 6). These have been structured using the broad level research areas defined in Section 6.1.

These research questions have been developed based on the original work undertaken by NAQWG, further discussion and analysis by the project team of the management needs and knowledge requirements and some consideration of the material collated during the stocktake. These questions were used in the prioritisation process (Appendix 2) to create research priorities for known management issues (Section 8.2).

Table 6: Research questions for known management requirements

Management Domain / Research Area	Research Question	Management Need
PRESSURE		
Anthropogenic contributions (emission factors and uncertainty)	What are the emission factors for BaP and Benzene from different sources (woodburning and vehicles in particular)?	To facilitate more realistic scenario modelling of the impacts of management strategies for controlling pollutant emissions
	What is the range of uncertainty for emission factors, fuel use, appliance age/type profile etc information used in emissions inventories?	To facilitate more realistic scenario modelling of the impacts of management strategies for controlling pollutant emissions.
Dispersion models & meteorology	Are the commonly-used models for air quality management 'fit-for-purpose' or could other international modelling approaches (e.g. e.g., AERMOD, ADMS-Road) be introduced for New Zealand?	To help ensure emission reduction targets and AEEs based on modelling are credible and defendable
	Is there a need to improve meteorological inputs for modelling (to provide robust and easily updated data)?	To help ensure emission modelling uses consistent data to assist credibility.
Impact of chemistry and atmospheric processes (including secondary particles)	How important is secondary particulate and what impact will current AQ strategies have on its concentrations?	To allow secondary contributions to be accounted for and managed by targeting precursor emissions if required.

Management Domain / Research Area	Research Question	Management Need
	What is happening in the early hours of the morning, and during the winter with regard to chemistry and particle formation?	To understand the relationship between precursor emission sources and secondary particles for improving responses.
Source apportionment (including natural sources)	What is the contribution of natural sources to PM_{10} and $PM_{2.5}$ and what constitutes an exceptional exceedance involving natural sources?	To monitor the effectiveness of measures to reduce anthropogenic emissions by separating out the natural component.
	What is the particle size distribution and diurnal profile for natural sources?	To create targeted responses that address manageable sources
STATE		
Spatial variability	How do PM concentrations (and other pollutants) vary across an airshed and how can we cost effectively predict the location of peak concentrations?	To justify location of monitoring stations for NES-AQ compliances, location specific management or for other purposes.
Information gaps re air toxics (eg, BaP, PAH) & PM2.5	Are there non-NES-AQ contaminants (e.g. BaP, As, formaldehyde) that we should be measuring and comparing with NZ guidelines?	To meet air quality guidelines and standards, and prioritise management needs
Affordable monitoring methods	Are there alternatives to standard methods that can be used to more cost-effectively measure HAPs and other contaminants in the ambient air guidelines (eg formaldehyde) that will also provide reliable results?	To help fill the information gap re concentrations of HAPs found in NZ and to manage guideline contaminants (e.g. arsenic and BaP etc)
	What cost-effective real-time methods can be adopted for quantifying natural sources of PM (including marine aerosol and dust)?	Better manage anthropogenic PM emissions
	What cost-effective methods should be adopted for quantifying the key constituents of PM (e.g. organic and elemental carbon, sodium, chlorine, potassium, nitrate, sulphate and ammonium)?	Quantify and manage the main constituents of PM_{10} and $PM_{2.5}$
	Can cost-effective methods be developed for non-NES-AQ contaminants (e.g. BaP etc)?	Quantify and manage guideline contaminants (e.g. arsenic and BaP etc)
Measurement (national consistency & QA & representativeness)	What is the cost and benefits of standardised modelling practices (eg arbitration panels, good practice guides, exemplars, certificate of modelling competency etc) to improve effectiveness of model use?	To help ensure emission reduction targets and AEEs based on modelling are credible and defendable.
	What are the costs and benefits of establishing a national AQ monitoring programme, including data repository, for PM_{10} and other contaminants?	To produce high quality and nationally consistent monitoring data most cost-efficiently that can be accessed through one portal and has long term security of storage.

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Management Domain / Research Area	Research Question	Management Need
Measurement (national consistency & QA & representativeness) (Cont.)	What are the cost and benefits of establishing a - national procedures for monitoring and national air quality monitoring training programme, including and a national facility for servicing and calibrating monitoring instruments and auditing monitoring sites?	To produce high quality and nationally consistent monitoring data most cost-efficiently.
	What cost-effective monitoring methods can and should be used for other guideline contaminants (e.g. BaP, formaldehyde, arsenic)?	To quantify and manage guideline contaminants (e.g. arsenic and BaP etc)
	Could alternative methods of screening or measurement be used to best locate equipment and/or reduce cost of monitoring $PM_{2.5}$ and PM_{10}?	To produce high quality and nationally consistent monitoring data most cost-efficiently.
IMPACT of State		
Human health effects (including. natural sources & air toxics)	Are there health effects from natural sources of PM and how do these contribute to the overall impact?	To understand the impact of natural sources on health in order to prioritise management response.
	What health impacts are associated with airborne soil contaminated with agrichemicals and pathogens?	Prioritising management need and ensuring the issues areaddressed
	What are the hydrogen sulphide odour threshold levels for communities exposed to hydrogen sulphide as opposed to those who are not?	For the assessment of specific activities (geothermal power developments and also WWTP's, composting operations etc)
	What are the potential health effects in communities/populations exposed to current concentrations of air toxics and are the current MfE ambient air guidelines still relevant?	To manage those contaminants likely to have the greatest impact in NZ and set appropriate guidelines/standards
Social consequences	Are the most susceptible and exposed populations being adequately protected?	To get the best outcomes from a health perspective by targeting management responses
	How much does air quality affect amenity values and influence their decisions (i.e where you live)	To help understand the wider impacts of air quality on communities
RESPONSES to Pressure-State		
Influencing human behaviour & understanding barriers to change	How can we influence perceptions and behaviour of householders or motorists to improve ambient air quality?	For better buy in from the community and a greater chance of meeting guidelines and standards
	What is the relative importance of the various barriers (eg lack of insulation, fuel poverty) to adopting clean heat to improving air quality? And how can these barriers be overcome?	For better buy in from the community and a greater chance of meeting guidelines and standards

Management Domain / Research Area	Research Question	Management Need
Multi-pollutant management	What other approaches could be used to reduce emissions from wood burners (large-scale solutions, technology, gross emitters etc) transportation? Would these also reduce concentrations from contaminants such as BaP, $PM_{2.5}$ and arsenic?	To provide a better guarantee of NES-AQ compliance and possibly other standards/guidelines
	Are the guideline contaminants being addressed (in both terms of regional monitoring and policies) in a nationally consistent and robust manner?	To understand how we might increase and improve the response to risks posed by guideline contaminants.
	How much will our policies on PM_{10} improve/drive reductions of other contaminants and will this be enough to meet other standards and guidelines?	To understand integrated outcomes for improved responses
Technological solutions	Can technological advances in emissions control (eg for domestic burners) achieve emissions reductions whilst still allowing domestic burning to continue?	To provide a better guarantee of NES-AQ compliance and possibly other standards/guidelines
Broader solutions (inter-relationships energy/housing/climate change)	Are measures adopted at the national and regional level the most effective for managing PM_{10} and associated contaminants (e.g. are there broader infrastructure/energy, transport related solutions that may be more effective)?	To provide a better guarantee of NES-AQ compliance
RESPONSE - Effect on "Impact"		
Understanding effectiveness of responses	Are risks to health decreasing in response to lower PM concentrations (i.e., are we seeing the same improvements in health from reductions in wood smoke as we would from motor vehicle dominated PM and are they similar to that reported overseas)?	Ensure strategies target those sources with the greatest impact on the health of the population
Understanding effectiveness of responses (Cont.)	Are current evaluation methods (inventories, dispersion modelling, receptor modelling) the most cost effective and providing quality outcomes? Are there alternative methods to emission inventories for source attribution that better link emissions and concentrations?	To provide more certainty regarding NES and guideline compliance, and to ensure that strategies are fair and not overly restrictive
	Are low emission wood burners delivering the reductions predicted relative to older burners in the field?	Determine if management response is effective and to know if further response is required
	Do we have the tools to accurately track progress towards AQ goals in a nationally consistent manner? Which are the best?	To allow reactive management based on the success or otherwise of current strategies and to facilitate and apply consistency in tracking progress towards NES-AQ compliance

6.3 Knowledge Gaps for Managing Emerging and New Issues

The following are key research questions identified for emerging and new management requirements (Table 7). Similar to the research questions for known management issues, these have been structured using relevant broad level research areas as defined in Section 6.1.

These research questions have been developed based on the original work undertaken by NAQWG, further discussion and analysis by the project team of the management needs and knowledge requirements and some consideration of the material collated during the stocktake. These questions were used in the prioritisation process (Appendix 2) to create research priorities for known management issues (Section 8.3).

Note: Many of the pressure and drivers needs for this area are covered either by related research questions in Section 6.2 (i.e. many of the research questions identified for known needs would also apply to $PM_{2.5}$)

Table 7: Research questions for emerging and new issues

Management Domain / Research Area	Research Question	Management Need
PRESSURE		
Information gaps re air toxics (eg, BaP, PAH) & $PM_{2.5}$	What $PM_{2.5}$ monitoring has been done in New Zealand and what does it tell us?	To understand the significance and risk of this potential management issue
	What are the similarities/differences with $PM_{2.5}$ and PM_{10} concentrations? How does the ratio change with location, weather patterns and season?	To understand the significance and risk of this potential management issue
	Are there other contaminants (for which there are no guidelines or standards) that we should be measuring? And are there cost-effective methods for monitoring?	To understand the significance and risk of health effects, determine need for standards/guidelines
STATE		
Measurement (national consistency & QA & representativeness	What are the feasibilities and costs of establishing and operating a representative national PM2.5 monitoring network?	To provide a clear consistent national understanding of state (and associated uncertainty) and regional variability
IMPACT		
Human health effects (including natural sources & air toxics)	What is the current state of knowledge regarding health impacts associated with $PM_{2.5}$ and it's sources in NZ?	To understand risk to health and need for new guidelines and standards?
	What does international research tell us about the impact of different contaminant mixes on health? What is the relevance of this to NZ?	To aid small-scale AQ management, protect against cumulative health effects

Management Domain / Research Area	Research Question	Management Need
	What $PM_{2.5}$ guideline, standard or policy should there be in NZ?	To improve health outcomes
	What non-standard/ guideline contaminants have been highlighted as potential health issues overseas and may also be an issue in NZ?	To understand risk to health and the need for new guidelines and standards
Exposure assessment and management	Should NZ shift focus from concentration exceedance to exposure (i.e. reducing exposure across the whole population instead of targeting hot spots where there are exceedances) as is happening internationally?	To get the best outcomes such as reduced morbidity and premature mortality from a health perspective by targeting management responses
RESPONSES to Pressure-State		
Scenario Assessments	How do we manage for a reduction in $PM_{2.5}$ and how does this differ from existing and proposed regional intervention strategies?	To improve health outcomes such as reduced morbidity and premature mortality
Multi-pollutant management	What is relationship of PM_{10} with other air toxics (multi-pollutant management) and how does this relate to emissions sources?	To understand integrated outcomes for improved responses
	Should management take into account contaminant mix (ie multi-pollutant) rather than managing on an individual pollutant basis? If so how could this be applied to NZ?	To manage air quality at a smaller community scale (i.e. different areas will have different mix of contaminants - particularly near industry etc)

7 Criteria and Prioritisation Process

The criteria and prioritisation process for evaluating the identified research question is a key element of the research strategy. This process has been developed to provide a clear, consistent and transparent tool for establishing the relative importance of air quality research needs. This involved the development of a draft prioritisation process which was trialed against some initial research questions and then further refined.

Following this, the broad research areas and the identified specific research questions for both 'know management requirements' and 'emerging or new' were sent to councils staff in an Excel spreadsheet that was set up to follow the developed prioritisation process.

The broad research areas that were identified (Section 6.1) were prioritised using a subjective ranking of their relative importance for their Region (1 Not Important, 2 Low Importance, 3 Moderately Important, 4 Very Important, 5 Highly important). Ten of the 16 councils provided feedback on priorities for these research areas. The result of this are presented and discussed in Section 8.

The prioritisation process for specific research questions (Sections 6.2 and 6.3) (Figure 6) was designed to assess the importance based on key criteria. These criteria included:

- Relative size of knowledge gap.
- Need to actively manage the issue.
- Scope of research to improve air quality outcomes.
- Relative risk (health, environment, management) posed by the issue.
- Potential for collaboration and co-benefits.
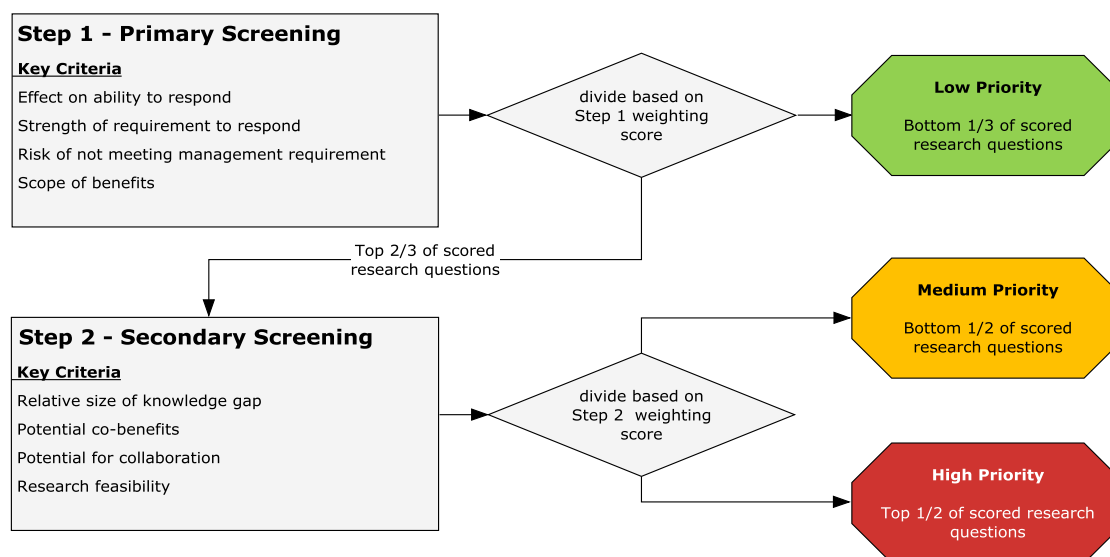
Figure 6: Prioritisation Process

Other requirements and variables which have been accounted for in the process are:

- the diversity of research needs across New Zealand geographically and the different priorities and issues between Councils.
- to provide a consistent approach to scoring and minimise subjectivity when scoring projects
- to be repeatable and enable projects to be re-run and re-ranked against new information and questions
- to enable research priorities to reflect a national approach as much as possible and provide the best information outcome for the most councils

- be specific and provide clarity to research providers and funding agencies

In summary the prioritisation process was set up to:

- run two separate streams of prioritisation – one for known management needs and one for emerging/new issues
- utilise a series of criteria for each (which vary slightly between each area of management)
- use a scoring system for the assessment of each research question – each project is scored out of 100 with different weightings on each criteria depending on how critical the criteria was viewed by NAQWG members
- provide higher scores to higher priorities
- use a two-step process (primary and secondary screening as shown in Figure 6 for each group of research questions (known management needs and emerging/new issues)
- allow the top 66% of projects identified in Step 1 of each process to proceed to Step 2
- allows research questions to be grouped into categories of high, medium and low research priorities rather than applying a specific ranking system

The full prioritisation process steps for both known management needs and emerging/new issues are outlined in Appendix 2. The research questions were structured into an Excel spreadsheet with the prioritisation process embedded. This was sent out to councils with instructions on how to complete.

The extent of feedback varied from the 16 councils with roles in air quality management:

- 10 provided prioritisation input on the broad research areas,
- 8 provided prioritisation input on the research questions for known management needs,
- 5 provided prioritisation input on the research questions for emerging/new management needs, and
- several of the councils did not proceed to the second stage of the prioritisation process for both known and emerging/new research questions.

The results of the prioritisation processes have been amalgamated from the spreadsheets returned by a number of the Councils. A summary and analysis of these results are provided in Section 8.

The prioritisation of broad research areas was seen to be relatively easy. But feedback on the process for research questions was:

- It took a lot of time
- Some of the questions were difficult to understand
- Could it be simplified?

Collation of the results from individual spreadsheets was difficult and time consuming as the order of questions in returned spreadsheets were different.

The value of a prioritisation process increases as more detail and specificity is provided. This does need to be balanced against the complexity and time required to undertake a process. To improve the future use of this approach the following improvements could be made:

- Some refinement and clarification of the research questions, but you need to be careful not to amalgamate or simplify questions too much as this will reduce the value gained from the process.
- Single step prioritisation process with a refined series of questions that focuses on the primary criteria.
- A more efficient feedback/collation process such as an online form linked to a database.

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8 Research Priorities

This section summarises the results of the prioritisation processes that have been undertaken as outlined in Section 7. The results are presented in the three defined main areas.

8.1 Broad Research Areas - Priorities

The identified board research areas were prioritised based on a score from 1 (low) to 5 (high). The feedback from councils was averaged to provide a ranking for these research areas (Table 8). The full results including rankings across councils are provided in Appendix 3.

This highest priority area was 'understanding and quantifying the effectiveness of management responses' this was ranked consistently high by all councils. Knowing how effective management responses are at reducing or mitigating the impacts of air quality is clearly very important.

Table 8: Priorities for broad research areas

Domain	Broad level research area	Ranking *	Average**
Pressure Understanding relationships between emissions and air quality	Understanding anthropogenic contributions (emission factors and uncertainty)	3	3.9
	Use of dispersion models & meterology information in defining pressure	13	2.8
	Understanding the impacts of chemistry and atmospheric processes (inc. secondary particles) on pressures	17	2.4
	Source apportionment (inc. natural sources)	9	3.2
State Describing & measuring air quality	Quantifying spatial variability of air quality	10	3.1
	Information gaps regarding air toxics	15	2.7
	Creating affordable monitoring methods	3	3.9
	Ensuring quality measurement of Air Quality (national consistency & QA & representativeness)	5	3.7
Impact of the State Quantifying effects of air quality	Understanding Human health effects of different air quality states (inc. natural sources & air toxics)	5	3.7
	Understanding variability of social susceptibility/consequences of poor air quality (social consequences)	15	2.7
	Methods for exposure assessment and management	13	2.8
Response- to "Pressure-State" Managing (response) the pressures (emissions) to improve the state (ambient air quality)	Tools and methods for creating scenario assessment to inform responses	12	3.0
	How to effectively apply dispersion modelling to define management responses	18	2.3
	How to effectively influencing human behaviour & understanding barriers to change	8	3.3
	Understanding multi-pollutant management to create integrated responses	10	3.1
	Identifying or creating technological solutions to improve air quality	2	4.0
	Methods or tools to create broader solutions (inter-relationships energy/housing/climate change)	7	3.5
Response effect on "Impact" Are responses actually reducing pressures (emissions). Is reduced pressure improving state and is health (impact) improving as a consequence?	Understanding and quantifying the effectiveness of management responses	1	4.6

* Ranking colour coding is based on top 1/3rd red, 2/3rd orange, bottom 1/3rd green
** Average for responses from 10 councils (See Appendix 16 for details)

The ability to have affordable, consistent and representative methods for monitoring state was also an area of importance. The area of technological solutions although ranked high overall was questioned by some respondents as to whether it was actually within councils responsibilities and that there were other funding sources for this work.

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A split in priorities for understanding the impacts of air quality occurred with 'understanding the health impacts' being high but the other aspects (social consequences, exposure assessment and management) being rank as low.

There is variability in how the broad areas are ranked between councils. This appears to be due to how councils have applied the scoring. This could reflect the wider range of issues in more populous regions and/or personal interpretation of ranking process (see Appendix 3 – Section 14.3).

Overall the broad areas of priority are:
- Tools for creating responses to poor air quality and knowing if these are effective.
- Understanding anthropogenic contributions
- Monitoring of state – affordable and representative
- Impacts on human health

8.2 Known Management Needs – Priorities for Research

The identified research questions for known management needs were prioritised based on feedback from councils who used the prioritisation process as outlined in Appendix 2.

The feedback from each council was used to give each question a ranking (1 = lowest score, 36 = highest score). These rankings where then averaged across all councils for each research question. The top third of the ranked research questions are shown in Table 9. The top third of the ranked research questions are shown in Table 10. The full results including rankings across councils are provided in Appendix 3.

The prioritisation of specific research questions for known management needs is generally consistent with the rankings provided under broad research areas. There is a strong focus on "response" questions (Table 9), followed by 'state' questions (Table 9 and Table 10).

The questions that get an overall high ranking are generally seen as high to medium importance by most council respondents. Those with a medium ranking tend to have more polarised rankings across councils (i.e. one or two councils with very high rankings and one or two councils with very low rankings). The low priority research question is generally considered ranked as low-medium (Appendix 3 – Section 14.2).

8.3 Emerging/New Issues – Priorities for Research

The identified research questions for emerging/new issues were prioritised based on feedback from councils who used the prioritisation process as outlined in Appendix 2.

The feedback from each council was used to give each question a ranking (1 = lowest score, 12 = highest score). These ranking where then averaged across all councils for each research question. The high and medium ranked research questions are shown in Table 11. The full results including rankings across councils are provided in Appendix 3.

The prioritisation of specific research questions for emerging/new issues is strongly focused around the areas of impacts on human health and the information gaps around air toxics.

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The research questions for emerging /new needs that get an overall high ranking are generally seen as high to medium importance by most council respondents. However, those with a medium or low ranking are more polarised rankings across councils (i.e. one or two councils with very high rankings and one or two councils with very low rankings) (Appendix 3 – Section 14.3).

Table 9: High priority research questions for known management needs

Research Question	Priority	Research Area	Management Need	DPSIR
How can we influence perceptions and behaviour of householders to improve ambient air quality?	27.8	influencing human behaviour & understanding barriers to change	For better buy in from the community and a greater chance of meeting guidelines and standards	Response
Are low emission wood burners delivering the reductions predicted relative to older burners in the field?	26.8	Understanding effectiveness of responses	Determine if management response is effective and to know if further response is required	Response
What is the range of uncertainty for emission factors, fuel use, appliance age/type profile etc information used in emissions inventories?	25.4	Anthropogenic contributions (emission factors and uncertainty)	To facilitate more realistic scenario modelling of the impacts of management strategies for controlling pollutant emissions.	Pressure
What cost-effective monitoring methods can and should be used for other guideline contaminants (e.g. BaP, formaldehyde, arsenic)?	24.5	Measurement (national consistency & QA & representativeness)	To quantify and manage guideline contaminants (e.g. arsenic and BaP etc)	State
Can cost-effective methods be developed for non-NES contaminants (e.g. BaP etc)?	24.3	Affordable monitoring methods	Quantify and manage guideline contaminants (e.g. arsenic and BaP etc)	State
Do we have the tools to accurately track progress towards AQ goals in a nationally consistent manner? Which are the best?	24.0	Understanding effectiveness of responses	To allow reactive management based on the success or otherwise of current strategies and to facilitate and apply consistency in tracking progress towards NES compliance	Response
Are there alternatives to standard methods that can be used to more cost-effectively measure HAPs and other contaminants in the ambient air guidelines (eg formaldehyde) that will also provide reliable results?	23.9	Affordable monitoring methods	To help fill the information gap re concentrations of HAPs found in NZ and to manage guideline contaminants (e.g. arsenic and BaP etc)	State
What is the contribution of natural sources to PM_{10} and $PM_{2.5}$ and what constitutes an exceptional exceedance involving natural sources?	23.8	Source apportionment (inc. natural sources)	To monitor the effectiveness of measures to reduce anthropogenic emissions by separating out the natural component.	Pressure
Are measures adopted at the national and regional level the most effective for managing PM_{10} and associated contaminants (e.g. are there broader infrastructure/energy related solutions that may be more effective)?	23.6	Broader solutions (inter-relationships energy/housing/climate change)	To provide a better guarantee of NES compliance	Response
Can technological advances in emissions control (eg for domestic burners) achieve emissions reductions whilst still allowing domestic burning to continue?	23.0	Technological solutions	To provide a better guarantee of NES compliance and possibly other standards/guidelines	Response
What is the relative importance of the various barriers (eg lack of insulation, fuel poverty) to adopting clean heat to improving air quality? And how can these barriers be overcome?	22.8	Influencing human behaviour & understanding barriers to change	For better buy in from the community and a greater chance of meeting guidelines and standards	Response
Are current evaluation methods (inventories, dispersion modelling, receptor modelling) the most cost effective and providing quality outcomes? Are there alternative methods to emission inventories for source attribution that better link emissions and concentrations?	22.0	Understanding effectiveness of responses	To provide more certainty regarding NES and guideline compliance, and to ensure that strategies are fair and not overly restrictive	Response

(See Appendix 3 for full results from responding councils)

Table 10: Medium priority research questions for known management needs

Research Question	Priority	Research Area	Management Need	DPSIR
Are there non-NES contaminants (e.g. BaP, As, formaldehyde) that we should be measuring and comparing with compare with NZ guidelines?	21.1	Information gaps re air toxics (eg, BaP, PAH) & $PM_{2.5}$	To meet air quality guidelines and standards, and prioritise management need	State
How much will our policies on PM_{10} improve/drive reductions of other contaminants and will this be enough to meet other standards and guidelines?	21.0	Multi-pollutant management	To understand integrated outcomes for improved responses	Response
Are there health effects from natural sources of PM and how do these contribute to the overall impact?	20.9	Human health effects (inc. natural sources & air toxics)	To understand the impact of natural sources on health in order to prioritise management response.	Impact
What are the potential health effects in communities/populations exposed to current concentrations of air toxics and are the current MfE ambient air guidelines still relevant?	20.6	Human health effects (inc. natural sources & air toxics)	To manage those contaminants likely to have the greatest impact in NZ and set appropriate guidelines/standards	Impact
What other approaches could be used to reduce emissions from wood burners (large-scale solutions, technology, gross emitters etc) and would these also reduce concentrations from contaminants such as BaP, $PM_{2.5}$ and arsenic?	20.6	Multi-pollutant management	To provide a better guarantee of NES compliance and possibly other standards/guidelines	Response
How do PM concentrations (and other pollutants) vary across an airshed and how can we cost effectively predict the location of peak concentrations?	20.1	Spatial variability	To justify location of monitoring stations for NES-AQ compliances, location specific management or for other purposes.	State
What cost-effective methods should be adopted for quantifying the key constituents of PM (e.g. organic and elemental carbon, sodium, chlorine, potassium, nitrate, sulphate and ammonium)?	19.5	Affordable monitoring methods	Quantify and manage the main constituents of PM_{10} and $PM_{2.5}$	State
Are the commonly-used models for air quality management 'fit-for-purpose' or could other international modelling approaches (e.g. e.g., AERMOD, ADMS-Road) be introduced for New Zealand?	19.4	Dispersion models & meteorology	To help ensure emission reduction targets and AEEs based on modelling are credible and defendable	Pressure
What cost-effective real-time methods can be adopted for quantifying natural sources of PM (including marine aerosol and dust)?	19.3	Affordable monitoring methods	Better manage anthropogenic PM emissions	State
What are the cost and benefits of establishing a - national procedures for monitoring and national air quality monitoring training programme, including and a national facility for servicing and calibrating monitoring instruments and auditing monitoring sites?	18.6	Measurement (national consistency & QA & representativeness)	To produce high quality and nationally consistent monitoring data most cost-efficiently.	State
What is the particle size distribution and diurnal profile for natural sources?	17.9	Source apportionment (inc. natural sources)	To create targeted responses that address manageable sources	Pressure
Are risks to health decreasing in response to lower PM concentrations (i.e., are we seeing the same improvements in health from reductions in wood smoke as we would from motor vehicle dominated PM and are they similar to that reported overseas)?	17.6	Understanding effectiveness of responses	Ensure strategies target those sources with the greatest impact on the health of the population	Response

(See Appendix 3 for full results from responding councils)

Table 11: High-medium priority research questions for emerging/new issues

Research Question		Research Area	Management Need	DPSIR
What PM$_{2.5}$ monitoring has been done in New Zealand and what does it tell us?	9	Information gaps re air toxics (eg, BaP, PAH) & PM2.5	To understand the significance and risk of potential management issue	pressure
What does international research tell us about the impact of different contaminant mixes on health? What is the relevance of this to NZ?	8.5	Human health effects (inc. natural sources & air toxics)	To aid small-scale AQ management, protect against cumulative health effects	Impact
What PM$_{2.5}$ guideline, standard or policy should there be in NZ?	8.4	Human health effects (inc. natural sources & air toxics)	To improve health outcomes	Impact
What is the current state of knowledge regarding health impacts associated with PM$_{2.5}$ and it's sources in NZ?	7.8	Human health effects (inc. natural sources & air toxics)	To understand risk to health and need for new guidelines and standards?	Impact
What are the similarities/differences with PM$_{2.5}$ and PM$_{10}$ concentrations?? How does the ratio change with location, weather patterns and season?	7.8	Information gaps re air toxics (eg, BaP, PAH) & PM2.5	To understand the significance and risk of potential management issue	pressure
What non-standard/ guideline contaminants have been highlighted as potential health issues overseas and may also be an issue in NZ?	6.7	Human health effects (inc. natural sources & air toxics)	To understand risk to health and need for new guidelines and standards	Impact
Should NZ shift focus from concentration exceedance to exposure (ie reducing exposure across the whole population instead of targeting hot spots where there are exceedances) as is happening internationally?	6.7	Exposure assessment and management	To get the best outcomes from a health perspective by targeting management responses	Impact
Are there other contaminants e.g. bioaerosols (for which there are no guidelines or standards) that we should be measuring? And are there cost-effective methods for monitoring?	6.6	Information gaps re air toxics (eg, BaP, PAH) & PM$_{2.5}$	To understand the significance and risk of health effects, determine need for standards/guidelines	pressure

(See Appendix 3 for full results from responding councils)

Summary

This strategy document represents the next step for the NAQWG in defining its research needs and priorities. This document has refined and extended the previous work undertaken by the NAQWG. Outcomes from this project include:

- The creation of a knowledge/gap assessment framework that can be used again in future to guide further assessment of research needs.
- A stocktake of New Zealand relevant research outputs on air quality which can be updated and used in future assessments of research needs and prioritisation.
- A refined set of broad research areas and specific research questions has been developed.
- A prioritisation process has been developed, trialed, and then applied to research areas and questions. This process can be refined further for on-going use by NAQWG
- An initial prioritisation of research areas and specific questions which identified a number of high priority research question with consistent regional support

Research priorities

The priorities identified for broad research areas are:

- Tools for creating responses to poor air quality and knowing if these are effective.
- Understanding anthropogenic contributions
- Monitoring of State – affordable and representative
- Impacts on human health

The specific research questions for known management that rated as high generally had a consistent level of support across councils. Most of the research needs in the high category related to creating and assessing the effectiveness of management responses, which is consistent with the broad research area priorities.

The specific research questions for emerging/new issues that rated as high generally also had a consistent level of support across councils. Most of the research needs in the high category related the areas of impacts on human health and the information gaps around air toxics.

The priority tables provide some clear indication of relative importance of research needs for councils. There is now opportunity for further refinement of the high priorities through discussion by NAQWG, after which potential project outlines can be developed for those which are seen need addressing first.

Process reflections

The strategy development process did not proceed entirely as planned in the initial scope of works. A robust gap analysis was not undertaken based on the difference between knowledge needs and the current knowledge (stocktake). This was due to a combination of factors including the extent of material found in the stocktake, the low awareness of much of the stocktake material, and the diversity of needs and views between councils. The research areas and key research questions where therefore primarilybased on previous work by NQWG, feedback from people interviewed during the process, and expert input from the project team.

Although the research questions that were presented were initially based on previous NAQWG work and went through a collective developed process there was still critique

and suggestions on questions during the wider prioritisation process. This highlights several points:

- There is inherent diversity in the roles, understanding, management needs and complexity of issues between regions
- More guidance on question structuring is required so that they are consistent in terms of the specificity of the topic and scope of the research need.
- Increased time and effort is required to develop questions and develop a consensus of understanding before undertaking a prioritisation process. This may require putting some specific context around each question.

The level of feedback from councils was lower than expected with only two thirds of council's responding to the broad research area priorities and about half the councils providing input to prioritisation of specific research questions. Although those who responded represent the majority of the population and geographic area the level of feedback is still considered an issue for future buy-in and support.

The prioritisation process of specific research questions was seen by many as a difficult and time consuming. There were suggestions that it should be simplified and stream lined. There is scope to improve the process by only running a single stage process and dropping some of the secondary questions. There is also a risk of oversimplifying the process to make it quicker to do but this can result is similar or general rankings. A robust assessment process does take some effort to get a useful outcome.

An initial objective of this research strategy project was to "outline possible projects, research providers and funding sources to meet these identified needs". This was not achieved within the resourcing of this project. Although a prioritised list of tangible research needs has been provided the existing material that has been developed by NAQWG on possible project has not been included as it does not easily align with the priorities identified.

Recommendations

The following are recommendations based on the process of developing this strategy document which would assist with its further development and review. They also provide a number of suggested next steps for the NAQWG in defining and promoting their research needs.

The recommendations are:

- NAQWG should consider how best to manage the diversity of needs, issues and resourcing that exists across its members as this makes the development of a single 'national' strategy difficult to achieve without clear guidance on management of the diversity. It may be more productive to understand the relative importance of key issues across regions and then develop issue based research strategies and priorities.
- NAQWG should review the priorities provided by this strategy (Section 8.1-8.3) and decide which of the high priorities should be advanced first so that outlines for possible projects can be developed.
- Review and refinement the key research questions for future prioritisation to ensure they provide clear understanding of the need for researchers and are representative of the right level of specificity (i.e. aimed at contaminant and drivers [PM_{10} and all contributors] or a specific activity [transport]). Development of some additional context for each research question would also help to ensure consistency in understanding during the prioritisation process.
- Refine the prioritisation process to a single stage process and reduce some of the secondary criteria questions. Also review the phrasing of the questions.
- To manage the feedback from a prioritisation process considered using an alternative to separated spreadsheets as these are difficult to collate together. Some online survey would be more effective.
- Encourage a wider level of input across the councils to refining the research questions and future prioritisation of these.
- A more thorough gap analysis should be undertaken in future to better define the gaps between current knowledge and management need for air quality management. This could initially be done by comparing stocktake documents against the identified research questions.
- The outcomes of this research prioritisation should be considered against any research strategy work being undertaken by other agencies as they become available.

11 References

Ancelet, T., Davy, P.K., Trompetter, W.J., Markwitz, A., and Weatherburn, D.C. (2012): A review of air particulate matter research in New Zealand: Where are we and where should we go from here?. Air Quality and Climate Change, Vol 46. No. 2. May 2012. Pg 34-42.

Beca Infrastructure Limited (2012) Air Quality Monitoring Programme. Report for Ministry for the Environment (in Draft.)

Kuschel, G. and Bluett, J. (2010) Stocktake of Transport Related Air Pollution (TARP) research in New Zealand – report prepared for NZTA.

Ministry for the Environment (2007): Environment New Zealand - 2007 State of the Environment Report, December 2007. (Ref 847).

Ministry for the Environment (2008): Good Practice Guide for Assessing Discharges to Air from Industry, June 2008.

12 Appendix 1 – Stocktake of current resources

12.1 PRESSURE

Relevance[2]	Author	Title	Organisation publishing	Date of pubn.	Focus of information
10	Ancelet T., Davy P., Trompetter WJ., Markwitz A., Weatherburn DC	A review of air particulate matter research in New Zealand: where are we and where should we go from here?	Prepared by GNS and University of Victoria Wellington. Published in Air Quality and Climate Change Volume 46 Issue 2 (May 2012)	2012	This work provides an overview on air particulate matter (PM) research in New Zealand with a focus on particle composition analyses. Many urban areas in New Zealand experience poor air quality during the winter as a result of PM pollution. It is evident from the studies presented here that domestic heating emissions from wood burning are the dominant source of PM during the winter throughout the country. It is also clear that concentrations of potentially harmful species associated with PM, such as benzo(a)pyrene and arsenic, are elevated during the winter in many areas, to the extent that these species may exceed guideline concentrations. The primary purposes of PM compositional studies are to better understand the sources and the potential for harmful health effects so that air pollution can be more effectively managed. Suggestions for further study are provided, with an emphasis on better understanding long-term trends in PM pollution and its components. We anticipate that the implementation of these suggestions will provide for better management of air quality throughout New Zealand.
7	Ancelet T., Davy P., Mitchell T., Trompetter WJ., Markwitz A., Weatherburn DC	Identification of particulate matter sources on an hourly time scale in a wood burning community.	Prepared by GNS, Victoria University and Greater Wellington Regional Council. Published in Environmental Science and Technology 2012 Volume 46, Issue 9 pp 4767-4774	2012	Particulate matter (PM) sources at two different sites in a rural town in New Zealand were investigated on an hourly time-scale. Streaker samplers were used to collect hourly, size-segregated $PM_{10-2.5}$ and $PM_{2.5}$ samples that were analysed for elemental content using ion beam analysis techniques. Black carbon concentrations were determined using light reflection and PM_{10} concentrations were recorded using collocated continuous PM monitors. The use of elemental speciation combined with PM_{10} concentrations for source apportionment on an hourly time-scale has never been reported and provides unique and useful information on PM sources for air quality management.

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[2] This is based on the high, medium, low or not seen assessments provided by four councils (Then ranked to provide - Gold = score 7+, Sliver 3-6, Bronze 1 or 2, 0 = white)

Relevance[2]	Author	Title	Organisation publishing	Date of pubn.	Focus of information
7	Ancelet T., Davy PK., Trompetter WJ., Markwitz A., Weatherburn DC	A comparison of particulate and Particle-phase PAH Emissions from a modern wood burner with those of an old wood burner	Prepared by GNS and University of Victoria Wellington. Published in Air Quality and Climate Change Volume 44 Issue 3 (August 2010)	2010	In an effort to establish reliable emission factors and assess wood burner improvements, particle-phase PAH emissions were determined for the combustion of pine under different operating conditions from a modern, NES-compliant wood burner and an older non-compliant burner.
9	Ancelet T., Davy PK., Trompetter WJ., Markwitz A., Weatherburn DC	Characterisation of Particulate matter emissions from a modern wood burner under varying conditions	Prepared by GNS and University of Victoria Wellington. Published in Air Quality and Climate Change Volume 45 Issue 2 (May 2011)	2011	Particulate matter emissions associated with the combustion of three wood species commonly burned in New Zealand were measured and the concentrations of particle phase polycyclic aromatic hydrocarbons (PAHs) and inorganic elements were determined under different operating conditions. The data presented in this study improves the current knowledge base for pollutants emitted from wood combustion and their emission factors.
4	Ancelet T et al	Sources of particulate matter on an hourly time-scale during the winter in a small city	Prepared by GNS science and submitted to Environmental Science and Technology	2012	
0	Appelhans A., Sturman A., Zawar-Reza P	Modelling emission trends from non-constant time series of PM_{10} concentrations in Christchurch New Zealand	Prepared by University of Canterbury. Published in International Journal of Environment and Pollution 2010 Vol 43, No. 4 pp 354-363	2010	This paper presents an attempt to model the trend of emissions through analysis of a time series of PM_{10} concentrations in Christchurch, New Zealand. Emissions are not constant over time, but show high seasonality. Fluctuations are removed by creating a time series in which concentrations do not show dependency on ambient air temperature. Remaining meteorological influences are removed through multiple linear regression. Finally, a moving average filter is applied to reveal the low-frequency trend in the residuals of the meteorologically adjusted time series. The modelled trend shows a peak in emissions in 2001-2002 with a steady decrease thereafter.
2	Appelhans T., Zawar-Reza P	A modelling study of particulate matter dispersion under dominant surface wind regime modes in Christchurch New Zealand	Prepared by University of Canterbury. Published in Air Quality and Climate Change Volume 44 Issue 1, Feb 2010	2010	In this study, TAPM is modified to ignore synoptic forcings yet still produce terrain induced flows that are common features over the Canterbury Plains in New Zealand. In addition, surface-based climatology for two different regimes is assimilated into the model in order to study their effects on temporal evolution of PM_{10}.
1	Bluett J., Dey K	On-road measurement of vehicle emissions in	Prepared by NIWA for Greater Wellington Regional Council -	2007	

Relevance[2]	Author	Title	Organisation publishing	Date of pubn.	Focus of information
		the Wellington region. Report CHC2007-123	Report		
5	Bluett J., Wilton E., Ponder-Sutton A	Assessing long-term trends in PM_{10} emissions and concentrations in Nelson	Prepared by NIWA/Environet for Nelson City Council - NIWA report ELF09213	2009	The objectives of this study are to advise NCC on: Real time methods for assessing trends in PM10 concentrations and methods for assessing trends in PM_{10} emissions with time - in particular how to use information on changes in household heating methods and industry emission changes to track progress compliance with the NES
2	Bluett J., Fisher G	Validation of a vehicle emission model using on-road emission measurements	Prepared by NIWA and Endpoint for 17th Clean Air and Environment Conference, Hobart 3-6 May 2005	2005	This paper undertakes a comparison between modelled and measured vehicle emissions of carbon monoxide. The measured vehicle emissions of CO were compared to modelled emissions provided by the NZ Traffic Emission rate Database.
7	Broadbent A., Cullen NJ., Zawar-Reza P	Wintertime numerical modelling of PM_{10} air pollution in Milton, Otago, New Zealand: boundary layer structure, effects of data assimilation and reaching National Environmental Standards	Prepared by University of Otago and University of Canterbury. Published in Air Quality and Climate Change Volume 44, Issue 4 (November 2010)	2010	This paper uses observations and The Air Pollution Model (TAPM) to examine the atmospheric processes controlling air pollution dispersion for the period May 1st - August 31st 2008 in the small town of Milton, located in the southern part of New Zealand. Similar to other small towns in the region, using TAPM to assess the sensitivity of the Milton township to a range of emission scenarios suggests a 50% reduction in both industrial and domestic PM_{10} emissions (a total of 208 kg day-1) is required to adhere to the Air Quality National Environmental Standards (AQNES) target of one exceedance per year.
3	Cavanagh JE	In-home testing of particulate emissions from NES-authorised Wood burners: Compressed wood products versus firewood	Landcare Research - Contract Report LC0809/025 - Prepared for FRST	2008	Report documents a preliminary assessment of particulate emissions from NES-authorised wood burners burning compressed wood products (fire logs) and operated under real-life operating conditions

Relevance[2]	Author	Title	Organisation publishing	Date of pubn.	Focus of information
5	Conway J., Spronken-Smith RA., Zawar-Reza P	The Clean Air Down there? Spatial Patterns of particulate matter pollution in Invercargill, New Zealand	University of Otago, University of Canterbury. Published in Clean Air and Environmental Quality Volume 41 Issue 3 (2007)	2007	This research explored the causative factors and spatial patterns of PM_{10} during nights of high pollution in the southern city of Invercargill, New Zealand. Mobile traverses measuring PM_{10} and meteorological variables were conducted in early winter during pollution episodes. The study revealed a complex and dynamic meteorological and particulate environment in operation, including strong temperature inversions, large emissions from domestic sources, transport of PM_{10} by diurnally switching winds, and spatially variable PM_{10} concentrations.
8	Cullen NJ., Conway J., Zawar-Reza P., Spronken-Smith RA	Further assessment of the atmospheric controls on night-time air pollution dispersion in Alexandra, Central Otago, New Zealand from idealised modelling experiments	Prepared by University of Otago and University of Canterbury. Published in Air Quality and Climate Change Volume 46, Issue 1 (February 2012)	2012	This research uses observational data and idealized sensitivity runs using a regional atmospheric model to further characterize the atmospheric controls on air pollution dispersion in the Alexandra Basin (Central Otago, New Zealand), with a focus on the mechanisms responsible for the bi-modal evening peak that has been observed in Alexandra.
3	Davy P., Trompetter B., Markwitz A	Source apportionment of airborne particles at North Dunedin - GNS Science Consultancy Report 2011/131	Prepared by NIWA for Otago Regional Council	2011	
2	Davy P., Trompetter B., Markwitz A	Source apportionment of airborne particles at Seaview, Lower Hutt. Report Number 2008/160	Prepared by GNS for Greater Wellington Regional Council	2008	
2	Davy P., Trompetter B., Markwitz A	Source apportionment of airborne particles at Wainuiomata, Lower Hutt. Report Number 2008/188	Prepared by GNS for Greater Wellington Regional Council	2009 a	

Relevance[2]	Author	Title	Organisation publishing	Date of pubn.	Focus of information
0	Davy P., Trompetter B., Markwitz A	Wairarapa air particulate matter screening surveys 2009: Elemental analysis and mass reconstruction. Report Number 2009/365	Prepared by GNS for Greater Wellington Regional Council	2009 b	
0	Davy P., Trompetter B., Markwitz A	Source apportionment of airborne particles at Raumati. Report Number 2011/83	Prepared by GNS for Greater Wellington Regional Council	2011 a	
0	Davy PK	Composition and sources of aerosol in the Wellington region of New Zealand	PhD thesis - Victoria University, Wellington	2007	
0	Davy P., Trompetter WJ., Markwitz A	Source apportionment of airborne particles in the Auckland Region. Client Report 2007/314	GNS Science	2007	
0	Davy P., Trompetter WJ., Markwitz A	Source apportionment of airborne particles in the Auckland Region - 2008 Update. Client Report 2009/165	GNS Science	2009	
2	Davy P., Trompetter WJ., Markwitz A	Source apportionment of airborne particles in the Auckland Region - 2010 Analysis. Client	GNS Science	2010	

Relevance[2]	Author	Title	Organisation publishing	Date of pubn.	Focus of information
		Report 2010/262			
2	Davy P., Trompetter WJ., Markwitz A	Source apportionment of PM_{10} at Tahunanui, Nelson 2010. Client Report 2010/198	GNS Science	2010	
0	Davy P., Trompetter WJ., Markwitz A	Elemental analyis of wood burner emissions, 2009. Client Report 2009/258	GNS Science	2009	
5	Davy P et al	Composition and source contributions of air particulate matter pollution in a New Zealand suburban town	Prepared by GNS Science. Published in Atmospheric Pollution Research 2012, Vol 3 p 143-147	2012	
1	Dirks KN., Johns MD., Hay JE., Sturman AP	A semi-empirical model for predicting the effect of changes in traffic flow patterns on carbon monoxide concentrations	Prepared by University of Auckland and University of Canterbury. Published in Atmospheric Environment Volume 37: pp2719-2724	2003	A simple semi-empirical model for predicting the effect of changes in traffic flow patterns on carbon monoxide concentrations is presented. The traffic component of the model requires average vehicle emission rate estimates for a range of driving conditions, as well as traffic flow data for the site of interest. The dispersion component of the model is based on a modified empirically optimised box model requiring only wind speed and direction information. The model is evaluated at a suburban site in Hamilton, New Zealand. Despite the simplicity of the model, produces reliable concentration predictions when tested on days with significantly different traffic flow patterns from those days with which the optimum model parameters were evaluated.
0	Dirks KN., Sturman A	The influence of local surface winds on air pollution concentrations at curb side monitoring stations	Published in Weather and Climate - Meteorological Society of New Zealand - Volume 24, pp 3-14	2005	

Relevance[2]	Author	Title	Organisation publishing	Date of pubn.	Focus of information
0	Dirks KN., Sturman A., Johns MD	Using health impacts to assess atmospheric carbon monoxide models	Prepared by the University of Auckland and the University of Canterbury. Published in Meteorological Applications Volume 13 Issue 1, pp 83-87	2006	This paper presents a technique for evaluating atmospheric carbon monoxide models based on the statistical properties of the uptake of carbon monoxide, rather than relying on traditional model evaluation measures. A simple semi-empirical atmospheric carbon monoxide model is used as an example to illustrate the approach.
	ESR	PM_{10} and Christchurch liquefaction silt	Prepared for the Ministry of Health as part of a contract for scientific services (report number FW11083)	2012	As a result of earthquake activity in Christchurch and surrounding areas from September 2010 onwards, large quantities of silt were brought to the surface in a number of suburbs. This occurred as a result of liquefaction of saturated silts below the surface, which forced this material above the ground. When the surface-deposited silt dries it can become airborne by wind or vehicle disturbance. Adverse effects from the airborne dust can be categorised as either nuisance or health-related. Possible health effects can result from: 1. dust particles in the air resulting in respiratory and eye irritation 2. particles smaller than 10 micrometres (μm), called PM10, can penetrate into the lungs resulting in a range of health effects Exposure to PM_{10} can result in serious health effects, including premature mortality. These are predominantly respiratory and cardiovascular related, but there is also evidence for adverse pregnancy-related outcomes such as low birth weight. Unlike other primary air pollutants, studies do not indicate that there is a safe threshold for PM_{10} exposure. Silt samples were collected by ESR from either exposed liquefaction material or silt removed from blocked sewers and subjected to a number of analyses to determine particle size distribution and composition. In addition, sub-samples were taken from artificial dust clouds generated in the laboratory and analysed for silica content. The key findings were that: • particles smaller than 10 μm (micrometres) were present in the liquefaction silt samples tested • the bulk liquefaction silt contained up to 65% silica

Relevance[2]	Author	Title	Organisation publishing	Date of pubn.	Focus of information
					• about 30% of the respirable dust was quartz.
5	Fisher G., Barclay J., Iremonger S., Thornton D	Targeted Air Pollution Reduction strategies using inventories and advanced modelling: Part 2 - Air shed Modelling	Endpoint Ltd, TRC Solutions, Bay of Plenty Regional Council. Published in Clean Air and Environmental Quality Volume 42 Issue 4 (2008)	2008	The relationship between emissions of air pollutants and ground level concentrations can be complex, especially in regions of complex topography and meteorology. The area around the city of Rotorua, New Zealand, is such a place with its location near a large lake, with surrounding hills and spatially variable emissions. The area experiences regular exceedances of the air quality standard for PM_{10}, and the regional council, Environment Bay of Plenty, has to enact measures to eliminate these. In order to be effective the council has used an advanced air shed model to identify which sources contribute to the exceedances, and the quantum of reduction required from each source category.
2	Gimson NR	Modelling the Air Quality of Auckland - Application to changing emissions in an ozone-limited atmosphere	NIWA - published in Clean Air and Environmental Quality Volume 39 Issue 1 (2005)	2005	Two year long simulations of the urban air quality of Auckland are carried out using CALGRID on a three km by three km horizontal grid, with meteorology simulated using the CALMNET diagnostic model. A good comparison between model results and pollution levels at remote monitoring sites is achieved and in particular results for NO2 and O3 are good at all sites - urban and remote
3	Gimson NR	Modelling the Air Quality of Auckland - a comparison between CALGRID and TAPM Simulations based on observed and modelled meteorology	Prepared by NIWA and published in Clean Air and Environmental Quality Volume 39 Issue 3 (2005)	2005	A series of urban air shed model simulations is carried out for Auckland, using CALGRID and TAPM running at 1km horizontal resolution. Several methods for incorporating meteorological information are examined.
0	Golder Associates	Evaluation of Baseline PM_{10} levels for Industrial Resource Consent Applications	Peer reviewed Technical Report	2009	

Relevance[2]	Author	Title	Organisation publishing	Date of pubn.	Focus of information
5	Graham B., Iremonger S	Targeted Air Pollution Reduction strategies using inventories and advanced modelling: Part 1 - Emissions inventory	Graham Environmental Consulting Ltd, Bay of Plenty Regional Council. Published in Clean Air and Environmental Quality Volume 42 Issue 4 (2008)	2008	The city of Rotorua, in the centre of the North Island, New Zealand, experiences elevated particulate concentrations during the winter months, and the ambient standard of 50 ug m-3 (24-h average) is regularly exceeded in some locations. This paper describes the ambient monitoring program, the results of a home heating survey, and the preparation of an emissions inventory for the Rotorua air shed.
3	Heydenrych C., Cudmore R., Gimson NR., Revell M., Fisher GW., Zawar-Reza P	CALPUFF model validation in New Zealand: Methodology and issues.	Prepared by Kingett Mitchell Limited for FRST. Part of FRST "Protecting New Zealand's Clean Air"	2005	Validation of the CALPUFF model in New Zealand conditions for industrial emissions from tall stacks and domestic heating emissions.
0	Jakob A., Craig JL., Fisher GW	Transport cost analysis: A case study of the total costs of private and public transport in Auckland	Prepared by University of Auckland and NIWA. Published in Environmental Science and Policy - Vol 9 (2006) pp 55-66	2006	Paper examining the use of motorised transportation and its impact as a social, environmental and economic problem. Examines external or "unpaid" costs and internal costs. It focuses on estimating the total cost of both private and public transport using a case study for Auckland.
4	Jiang N., Hay JE., Fisher GW	Classification of New Zealand Synoptic Weather Types and relation to the Southern Oscillation Index	Prepared by University of Auckland and NIWA. Published in Weather and Climate 25 pp 43-70 (2006)	2006	Obliquely rotated T-mode principal component analysis has been applied to the NCEP/NCAR geopotential height reanalysis data for winter months from 1958 to 1996 over the NZ region. A new set of ten representative weather types were identified with two being most dominant. The temporal characteristics of the ten synoptic weather types were analysed in relation to different phases of the Southern Oscillation Index.
1	Kingham S., Durand M., Harrison J., Cavanagh JE., Epton M	Temporal variations in particulate exposure to wood smoke in a residential school environment	Prepared by University of Canterbury, Landcare Research and University of Otago. Published in Atmospheric Environment 42 (2008) 4619-4631	2008	This research examines concentrations of PM_{10}, $PM_{2.5}$ and PM_1 inside and outside of a boarding school in Christchurch.

Relevance[2]	Author	Title	Organisation publishing	Date of pubn.	Focus of information
2	Kossmann M., Sturman AP	The surface wind field during winter smog nights in Christchurch and coastal Canterbury, New Zealand	Prepared by University of Canterbury. Published in International Journal of Climatology Volume 24, Issue 1 pp 93-108	2004	This study analyses surface wind fields during smog nights using data collected during the Christchurch Air Pollution Study 2000 (CAPS2000). Westerly land breezes and drainage winds from the foothills of the Southern Alps and the Canterbury Plains are evident in all coastal Canterbury towns, but local terrain features often complicate the wind fields. The effects of topographically induced flow splitting and non-stationary drainage wind convergence on urban air pollution dispersion identified here have not previously been studied in detail internationally and should receive greater attention in the future.
0	Kuschel G., Kingsland S	Sensitivity of the Christchurch Total Emissions Inventory to Possible Variations in Fuel Use and Emissions Factors. Canterbury Regional Council Report No U99/50	Canterbury Regional Council	1999	
8	Longley I., Gadd J	Preliminary exploration of high resolution PM_{10} measured inside wood-burning New Zealand Homes	Prepared by NIWA. Published in Air Quality and Climate Change Volume 45, Issue 1 (February 2011)	2011	Research aimed to observe typical PM_{10} concentrations inside typical New Zealand homes in which a wood-burner is used for domestic heating in winter. We further aimed to perform a preliminary analysis on the day-to-day variability in indoor PM_{10} and its determinants. Our results show that true exposure may be substantially higher in wood-burning homes compared to non-wood-burning homes and in the ambient air, and that the presence of an operating wood-burner is a substantial modifier of the relationship between ambient air quality and exposure.
1	Longley I., Olivares G., Khan B., Zawar-Reza P	The determinants of levels of secondary particulate pollution and nitrogen dioxide in urban New Zealand - Part 1. NIWA Client Report AKL2008-053	Prepared by NIWA for FRST	2008	Research concerned with levels of secondary sulphate and nitrogen dioxide of anthropogenic origin in the atmosphere of urban New Zealand. The work seeks to: review data on ambient concentrations in terms of NES, RAQT and WHO guideline compliance; Review the available data to scope its ability to describe and explain the determinants of ambient concentrations; trial some analyses that may help to improve our understanding of the processes leading to elevated concentrations
5	Longley I., Olivares, G	A review of regional and natural background PM_{10} in New Zealand	Prepared by NIWA for FRST	2008	This report focuses on the current state of knowledge regarding background PM_{10} and some existing and proven means of estimating it. This report is part of the "Protecting NZ's Clean Air" research programme

Relevance[2]	Author	Title	Organisation publishing	Date of pubn.	Focus of information
7	Longley ID., Harper S	Interpreting the influence of an urban valley micro-climate on PM_{10} concentrations from monitoring data	Prepared by NIWA. Published in Air Quality and Climate Change Volume 44, Issue 4 (November 2010)	2010	The analysis sought to establish the general relationship between surface wind and PM_{10} concentrations over the study area as a whole, and to investigate whether low wind conditions led to systematic fine-scale spatial variation in PM_{10} delineated by the valley-ridge terrain in the study area. A PM_{10} index was established from the average concentration of data from several sites to distinguish area-wide from locally specific air quality. The analysis has been used to inform the air quality assessment for a major motorway project planned to pass through the valley (for which the local monitoring was conducted). It is proposed that the analysis leads to a more robust and representative baseline assessment for project assessment receptors distributed over a wide spatial area.
0	McKendry IG., Sturman AP., Vergeiner J	Vertical profiles of particulate matter size distributions during winter domestic burning in Christchurch, New Zealand	Prepared by University of British Columbia, University of Canterbury, University of Innsbruck. Published in Atmospheric Environment Volume 38: pp4805-4813	2004	This study describes the application of a novel technique for obtaining vertical profiles (0– above ground level) of PM size distributions in a highly polluted setting dominated by domestic burning of wood and coal. Results confirm the usefulness of the deployment of miniature optical PM instruments on tethered balloons in cool, humid, polluted conditions. Such measurements allow the proper evaluation of the current generation of air pollution dispersion models.
6	Mills D	Balclutha spatial PM_{10} study	Otago Regional Council	2011	A study into the spatial patterns of PM_{10} in Balclutha to improve the understanding of winter air quality patterns. In this study, data on land use patterns, fuel type usage, weather data and PM_{10} levels were collected and analysed to explain differing air quality patterns around Balclutha.
11	Ministry for the Environment	Good Practice Guide for Assessing Discharges to Air from Industry - ME880	Ministry for the Environment	2008	This guide is one of a series of good practice guides developed by MFE. There is a strong relationship between the guides (ME880, 881 and 522). This guide is specific to Assessing discharges to Air from Industry. The guide outlines the regulatory framework for the assessment process, provides guidance on appropriate levels of assessment, provides guidance on characterising both the development and receiving environment, identifies air quality criteria by which impacts should be assessed and provides guidance on key considerations under the NES air quality
8	Ministry for the Environment	Good Practice Guide for Assessing Discharges to Air from Transport - ME881	Ministry for the Environment	2008	This guide is one of a series of good practice guides developed by MFE. There is a strong relationship between the guides (ME880, 881 and 522). This guide is specific to Assessing discharges to Air from Transport. The guide outlines the regulatory framework for the assessment process, provides guidance on appropriate levels of assessment, provides guidance on characterising both the development and receiving environment, identifies air quality criteria by which impacts should be assessed and provides guidance on key considerations under the NES air quality

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8	Ministry for the Environment (prepared by Colleen Kelly, Suri Mules, Wayne Webley)	Warm Homes Technical Report - Real life Emissions Testing of Wood Burners in Tokoroa - ME814	Ministry for the Environment	2007	The aim of this study was to gain a better understanding of emission factors for wood burners that are compliant with the NES Standard for Air Quality. The study considerably furthers our knowledge about emissions from NES compliant wood burners and in particular enables a comparison to be made between the emission factors from old non-compliant wood burners and the NES compliant burners
5	Ministry for the Environment (prepared by Colleen Kelly, Suri Mules, Wayne Webley	Warm Homes Technical Report - Real life Emissions Testing of Pellet Burners in Tokoroa - ME813	Ministry for the Environment	2007	The aim of this study was to gain a better understanding of emission factors for wood-pellet burners. Wood pellet burners were chosen because there is very little data on their real-life emissions. These burners are an emerging technology in NZ and their numbers are expected to grown which will make it increasingly important to have an understanding of their emissions and how these may affect an air shed
5	Ministry for the Environment	Amenity effects of PM_{10} and TSP concentrations in New Zealand - AQTR 41	Prepared by Environet Ltd for Ministry for the Environment	2003	This technical report comprises a review of the amenity impacts (types and extent) of PM_{10} and TSP concentrations in NZ
1	Ministry for the Environment (prepared by NIWA for MFE)	Transport Emissions Study - Modelling and Monitoring	Ministry for the Environment and Ministry of Transport	1997	Study commissioned to investigate the nature and impacts on air quality of emissions from motor vehicles in NZ to establish: what are the key factors affecting roadside pollution levels and how can we accurately predict pollutant concentrations near roadways - to provide technical input for formulating future policy and management options in the transport sector
11	Ministry for the Environment	Good Practice Guide for Atmospheric Dispersion Modelling - ME 522	Prepared by NIWA, Aurora Pacific Ltd and Earth Tech Incorporated for Ministry for the Environment	2008	This guide is one of a series of good practice guides developed by MFE. There is a strong relationship between the guides (ME880, 881 and 522). This guide is specific to Atmospheric Dispersion Modelling. The purpose of this guide is to provide good-practice protocols for modelling the dispersion of discharges to air from industrial complexes in New Zealand. The guideline provides recommendations which direct modellers towards adopting a best practice approach.

Relevance[2]	Author	Title	Organisation publishing	Date of pubn.	Focus of information
5	Mulliner T., Hager T., Spronken-Smith R	Temporal patterns of PM_{10} in a small southern town in New Zealand	Timaru District Council, University of Otago. Published in Clean Air and Environmental Quality Volume 41 Issue 2 (2007)	2007	This paper investigates seasonal patterns and annual trends of PM_{10} concentrations in the small town of Mosgiel located in Otago, southern New Zealand. A second aim is to explore the relationship between PM10 concentrations and concomitant meteorological factors.
3	Otago Regional Council	Mosgiel spatial PM_{10} study	Otago Regional Council	2009	A study into the spatial patterns of PM_{10} in Mosgiel to improve the understanding of winter air quality patterns. In this study, the density of residential and industrial land use was identified to help explain spatial differences in air quality and a spatial monitoring exercise was carried out looking at the actual air quality in different sectors of the town during evenings with high PM_{10} concentrations
5	Palmer P., Mann JD	How toxic are fine particles emitted from home fires in Christchurch, New Zealand	Published in the New Zealand Medical Journal	2011	Fine particles (PM_{10}) in the air in Christchurch have been estimated to be a considerable health hazard, and 9.1% of all deaths have been attributed to them. Concentrations often exceed the national standard. The particles come from wood-burning stoves and hydrocarbon-burning traffic and industry. This study asks whether the particles from these sources are equally toxic, and whether a standard based on concentration of particles is appropriate as a measure for devising regulatory controls to safeguard public health.
5	Scott AJ	Real life emissions from residential wood burning appliances in New Zealand	Environment Canterbury - MFE Sustainable Management Fund	2005	A study jointly funded by Environment Canterbury, Nelson City Council and the Ministry for the Environment through the Ministry's Sustainable Management Fund was conducted in 2003 and 2004 to determine real-life emissions from low emission residential wood burning appliances
3	Scott AJ., Sturman AP	Beyond emission inventories - Tracking the main sources of airborne PM in Christchurch, New Zealand	Environment Canterbury, University of Canterbury. Published in Clean Air and Environmental Quality Volume 40 Issue 4 (2006)	2006	Emission inventories consistently identify residential heating as the main wintertime source of particulate matter (PM) less than 10 microns in diameter (PM_{10}) and fine particles (PM2.5) in Christchurch, New Zealand. However, these findings have been disputed by some in the community and, in response, an investigation of an alternative source attribution technique was conducted. The Christchurch Source Apportionment Study (CSAS) collected speciated data over 159 days in 2001/2. During the winter, particles were predominantly of combustion or secondary particulate origin and chemical species associated with marine environments were more abundant in summer. Source apportionment, conducted by the Positive Matrix Factorisation (PMF) receptor model, indicated that five sources were primarily responsible for $PM_{2.5}$ in Christchurch. These were identified as wood combustion, motor vehicles, marine aerosol, secondary particulate and aged aerosol, and accounted for 87% of summertime PM2.5 and 94% of wintertime $PM_{2.5}$. The chemical composition of the five sources were consistent with other observations, and the results provided independent verification that residential heating is the greatest contributor (79%) to wintertime $PM_{2.5}$ in Christchurch.

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0	Scott A	Source apportionment and chemical characteristion of airborne fine particulate matter in Christchurch New Zealand	PhD thesis - University of Canterbury	2005a	
0	Scott A	Draft Timaru source apportionment study	Enivironment Canterbury Report No 12/??	2012	
2	Senaratne I., Kelliher FM., Triggs CM	Source Apportionment of PM_{10} during cold, calm weather in Christchurch New Zealand: Preliminary results from a receptor model	University of Auckland, Landcare Research, Department of Statistics	2005	In Christchurch, New Zealand, PM_{10} levels increase during cold, calm weather. To apportion sources, we deployed a high-volume air sampler to collect PM_{10} and directly sampled particles from seven potential emission sources. Elemental concentrations were determined by inductively coupled plasma/mass spectroscopy (ICP/MS). Source identification used principal component factor analysis (PCFA) with Varimax rotation, while apportionment used an absolute PCFA receptor model. Sources were sea spray, combustion for domestic heating, combustion associated with vehicles, and suspended road dust.
4	Sherman M., Fisher G	The relationship between average annual, peak concentrations and exceedances of PM_{10} - a discussion document and draft paper	Endpoint Consulting partners - Part of FRST "Protecting New Zealand's Clean Air"	2006	Study examines the relationships between a site's annual average PM_{10} concentration and: the peak annual PM_{10} concentration; the number of times per year that the 24 hour mean concentration exceeds the air quality standard; the number of times per year that the 24 hour mean concentration exceeds a nominal indicator value
0	Smith J., Wilton E., Baynes M	Multifuel burner emissions and air quality regulations at Reefton - NIWA client report CHC2007-0	Prepared for West Coast Regional Council by NIWA/Environet	2007	The purpose of this report is to evaluate options for retaining coal burning as a home heating choice for households in Reefton whilst reducing PM_{10} to meet the NES.
6	Smith J., Bluett J., Wilton E.,	In Home testing of Particulate Emissions from	NIWA Client Report: CHC 2008-092	2007	The objective of this project was to derive a robust PM_{10} emission factor for representing NES authorised wood burners in dispersion modelling applications and emission inventories

Relevance[2]	Author	Title	Organisation publishing	Date of pubn.	Focus of information
	Mallet T	NES - authorised wood burners: Nelson, Rotorua and Taumarunui			
1	Sturman A	An evaluation of the possible effects of recirculation on ozone concentrations in the Christchurch area	University of Canterbury, Centre for Atmospheric Research	2000	
0	Sturman A., Kossman M., Spronken-Smith R., Zewar-Rezar P., Boorer S	The air pollution meteorology of the Timaru Area. Environment Canterbury Report No U02/93	Canterbury Regional Council	2002	
4	Tate A., Spronken-Smith RA	A preliminary Investigation of the Air Pollution meteorology of Alexandra. Central Otago, New Zealand	University of Otago. Published in Clean Air and Environmental Quality Volume 42, Issue 2 (2008)	2008	This research explored the air pollution meteorology of the small Central Otago town of Alexandra, New Zealand. Alexandra suffers from very poor air quality during winter resulting from the high use of solid fuels for domestic heating during atmospheric conditions that are not conducive to dispersion. An existing one and a half year dataset provided the basis for analysing the relationships between PM_{10}, temperature and wind speed to develop a predictive model. The results show that sub-freezing temperatures and wind speeds below 0.5 m s-1 at 0800 or 0900 hours can be used to predict high levels of PM_{10} that evening. However, these thresholds only accounted for approximately 60% of the high pollution days. Case studies revealed that the air pollution meteorology in Alexandra is complicated by the interaction of various scales of drainage flow, the occurrence of hoar frost, and possible variation in domestic heating emissions.
8	Tate A., Spronken-Smith RA	Wintertime PM_{10} measurements and modelling in Alexandra, Central Otago, New Zealand: Understanding the bi-modal peak in evening air pollution	University of Otago. Published in Clean Air and Environmental Quality Volume 45, Issue 3 (August 2011)	2011	This research uses observational data and The Air Pollution Model (TAPM) to explore atmospheric processes controlling PM_{10} air pollution in Alexandra (Central Otago, New Zealand). As observed elsewhere, high air pollution days in Alexandra are characterised by two primary emission peaks, a morning peak at 0800 hours and an evening peak at 1800 hours, reflecting the time of day that domestic heating appliances are used. However, on high air pollution days an unusual bi-modal evening peak in PM_{10} concentration also occurs, which has not been observed in other New Zealand towns. This paper investigates meteorology and links with this peak for the Alexandra basin. Based on the current number of exceedances, large reductions in domestic emissions are

Relevance[2]	Author	Title	Organisation publishing	Date of pubn.	Focus of information
					required if Alexandra is to reach the targets set by the AQNES.
2	Titov M., Zawar-Reza P., Sturman A	Application of MM5 and CAM x4 to local scale dispersion of particulate matter for the city of Christchurch, New Zealand	Prepared by University of Canterbury and presented at 18th Conference of the Air and Waste management Associated. Minneapolis, USA June 2005	2005	Modelling results from the highest resolution computational grid are compared with the observed meteorology and dispersion for winter 2000 when the Christchurch Air Pollution Study was underway.
1	Trompetter WJ., Davy PK., Markwitz A	Influence of environmental conditions on carbonaceous particle concentrations within New Zealand.	Prepared by GNS. Published in Journal of Aerosol Science Vol 41 (2010) pg 134-142	2010	
4	Wilton E., Appelhans T., Baynes M., Zawar Reza P	Assessing long term trends in PM_{10} emissions and concentrations in Invercargill	Environment Southland - Envirolink Project Number ESRC223	2009	The purpose of this study is to evaluate the impact of year to year variability in meteorology on PM_{10} concentrations to evaluate the reasons for apparent changes in PM_{10} concentrations between 2003 and 2005 and 2006 to 2008.
11	Wilton E., Baynes M., Bluett J	Improving PM_{10} Emission Factors from Industrial Boilers in New Zealand - Stage 1	Prepared by Environet/NIWA for FRST	2008	This report is part of the FRST "Protecting New Zealand's Clean Air" Research program. It aims to improve industrial boiler emission factors used in emission inventories and for assessing environmental effects. The focus of this report is on PM10 and the emission factors used for PM_{10} are in relation to industrial coal, wood and LFO

Relevance[2]	Author	Title	Organisation publishing	Date of pubn.	Focus of information
7	Wilton E., Baynes M., Iseli J	New Zealand Sulphur Dioxide Industrial Emission Inventory - 2008	Prepared by Environet for Ministry for the Environment	2007	Ministry for the Environment has been requested by the National Air Quality Working Group to prepare a policy position on the WHO 2005 guidelines for SO2. This report undertakes one of the first steps towards determining a policy position on SO2 in NZ by quantifying the SO2 output from industrial discharges. The purpose of this report is to identify industry in NZ with significant discharges of SO2 and to quantify the daily SO2 emissions
5	Wilton E., Davy P., Smith J	Source identification and apportionment of PM_{10} and $PM_{2.5}$ in Hastings and Auckland. NIWA Client report CHC2007-137	Prepared by Environet, GNS and NIWA for FRST	2007	The contribution of different sources to PM_{10} and $PM_{2.5}$ concentrations was examined in Hastings and Auckland using receptor modelling. The research objectives were to: Show how results from receptor modelling studies may be used to check emission inventory results; demonstrate a method for determining the contribution of natural sources to PM_{10} concentrations; expand existing information on source profiles for New Zealand. This research was art of the FRST "protecting New Zealand's Clean Air" programme of work
6	Wilton E., Smith J., Gimson N., Phillips J	Source Apportionment and Modelling of PM_{10} in Hastings New Zealand	Prepared by Environet, NIWA, Golder Assoc and Hawkes Bay Regional Council. Published in Air Quality and Climate Change Volume 43 No 2 May 2009 31-39	2009	The research assists with air quality management in Hastings by: a) quantifying the contribution of natural PM_{10} sources (which cannot readily be mitigated in strategies for reducing PM_{10}); b) demonstrating a need to regulate domestic emissions beyond the urban boundaries of Hastings; and c) increasing certainty in the main source of PM_{10} and its relative contribution to the total PM_{10}.
5	Wilton E	Real life emissions testing of pre-1994 woodburners in New Zealand. Waikato Regional Council Technical Report TR2006/05	Prepared by Environet for Waikato Regional Council	2006	The difference between laboratory and real life emissions may be because of variability of woodburner operation, installation characteristics or fuel type and quality in real life circumstances. Because this variability applies to woodburners of all ages, emission factors currently used for older woodburners are also uncertain. The objective of this investigation is to establish a real life emission factor for pre-1994 woodburners.
3	Wilton E., Zawar-Reza P., Baynes M	Monitoring of Dust in the Hawkes Bay Region	Hawkes Bay Regional Council - prepared by Environet/NIWA	2009	
3	Wilton E	Natural source contribution to background PM_{10} in Awatoto			
1	Wilton E	Scoping Report Assessing natural	Environet	2009	

Relevance[2]	Author	Title	Organisation publishing	Date of pubn.	Focus of information
		sources contributions to PM_{10}			
0	Woodward-Clyde NZ Ltd	A Review of Available Evaluation Criteria for the Assessment of Air Quality Effects. Prepared by Woodward-Clyde NZ Ltd for Auckland Regional Council	Auckland Regional Council	2002	The report outlines a review of techniques and methodologies currently available for use in carrying out assessments of AEE's for discharges to air. The key issues relating to the assessment of air discharges were examined under 3 key broad areas: Determination of Process Emissions, Assessment Techniques and Evaluation Criteria. This report specifically relates to Evaluation Criteria. A separate report for Determination of process emissions and assessment Techniques is also included in this stocktake - see "A Review of Available Assessment Methodologies for Air Quality Effects".
0	Woodward-Clyde NZ Ltd	A Review of Available Assessment Methodologies for Air Quality Impact Assessments. Prepared by Woodward-Clyde for the Auckland Regional Council	Auckland Regional Council	2002	The report outlines a review of techniques and methodologies currently available for use in carrying out assessments of AEE's for discharges to air. The key issues relating to the assessment of air discharges were examined under 3 key broad areas: Determination of Process Emissions, Assessment Techniques and Evaluation Criteria. This report specifically relates to Determination of process emissions and Assessment Techniques. A separate report was produced for Evaluation criteria and is also included in this stocktake - see "A Review of Available Evaluation Criteria for the Assessment of Air Quality Effects".
2	Xie S., Clarkson T., Gimson N	Source Contributions to Ambient PM_{10} and implications for Mitigation - a case study	Public report reviewed by NES Research Advisory Group - Part of FRST "Protecting New Zealand's Clean Air"	2005	This report presents estimates of PM_{10} source contributions and analysis of mitigation effects by using air shed modelling in Masterton as a case study.
11	Xie S., Mahon K., Petersen J	Effects of fuel and operation on particle emissions from wood burners	Prepared by Auckland Regional Council (Auckland Council). Published in Air Quality and Climate Change Volume 46 Issue 1 (Feb 2012)	2012	Particle pollution from wood burners for home heating in winter is a significant air quality issue in many urban areas around the world. There are significant uncertainties in the quantities of particles discharged from the wood burners used by residents. A wood burner testing program has been carried out in Auckland to investigate the effects of important variables on emissions and measure emission factors reflecting real-life operations. Our results provide a critical input into domestic emission estimates and quantitative information for assessing options to effectively reduce domestic pollution from fires.

Relevance[2]	Author	Title	Organisation publishing	Date of pubn.	Focus of information
0	Zawar-Reza P., Kingham S., Pearce J	Evaluation of a year-long dispersion modelling of PM_{10} using the mesoscale model TAPM for Christchurch, New Zealand	Prepared by University of Canterbury. Published in Science of the Total Environment Volume 349 Issues 1-3 October 2005, pp 249-259	2005	This paper examines the utility of The Air Pollution Model (TAPM; version 2) in simulating meteorology and dispersion of PM_{10} for 1999 over the coastal city of Christchurch, New Zealand. Meteorology and PM_{10} dispersion results are statistically compared with the only permanent air pollution monitoring station available in order to evaluate the model's performance. Statistical measures such as the Index of Agreement (IOA) between modelled and measured data indicate that the model performs well. IOA is greater than 0.6 for meteorological variables, and various calculated skill scores place confidence in the model's performance. However, TAPM has a tendency to overestimate surface wind speed over urban areas during stagnant nocturnal conditions, resulting in quick flushing of pollutants.
2	Zawar-Reza P., Sturman A., Hurley P	Prognostic Urban-scale Air pollution modelling in Australia and New Zealand - a review	Prepared by University of Canterbury and CSIRO and published in Clean Air and Environmental Quality Volume 39 Issue 2 (2005)	2005	This paper reviews research conducted in the past two decades in urban-scale air quality modelling in Australia and New Zealand, with emphasis on prognostic models. With advances in computer technology - especially desktop computers - air pollution dispersion modelling is now a feasible undertaking not only for well funded research institutions, but also for air quality consultants.
1	Zawar-Reza P., Titov M., Sturman AP	Dispersion modelling of PM_{10} for Christchurch, New Zealand: an intercomparison between MM5 and TAPM	Prepared by the University of Canterbury and presented at 17th International Clean Air and environment Conference. Hobart 3-6 May 2005	2005	The performance of two geophysically based high-resolution mesoscale models in simulating the meteorology and dispersion of PM_{10} for the city of Christchurch are assessed. The modelling results are compared within the context of simulating meteorology and dispersion with a high resolution computational mesh.

12.2 STATE – IMPACT

Relevance	Author	Title	Organisation publishing	Date of pub.	Focus of information
4	Bluett J	The State of the PM$_{10}$ monitoring network within NES Air sheds: Benchmark Year - 2006	Prepared by NIWA for FRST	2006	Aims of this report are to: Present a benchmark review of the State of NZ's PM10 monitoring network in 2006 - the first year after the implementation of the NES; Make recommendations on enhancing the PM10 monitoring network; Highlight the major knowledge gaps on monitoring PM10 in NZ
3	Bluett J., Gimson NR., Wilton E., Fisher GW	Review and gap analysis of PM$_{10}$ monitoring in New Zealand	Prepared by NIWA, Environet and Endpoint Ltd for FRST	2005	The objective of this research is to complete a gap analysis of existing PM monitoring with recommendations for enhancements. Work carried out as part of FRST "Protecting New Zealand's Clean Air" programme
5	Bluett J., Wilton E., Franklin P., Dey K., Aberkane T., Petersen J., Sheldon P	PM$_{10}$ in New Zealand's urban air: A comparison of monitoring methods. NIWA Client report CHC2007-0	Prepared by NIWA, Environet and others for FRST	2007	The difference in mass concentrations from co-located gravimentric and equivalend PM10 monitoring has long been a concern for air quality professionals. Though individual co-location studies have been conducted at a number of locations to determine site specific data, there has been little research in NZ that compares these studies. By comparing data from a range of New Zealand environments and season a greater understanding of the differences between instruments can be obtained
0	Bolling AK et al	Health effects of residential wood smoke particles: the importance of combustion conditions and physicochemical particle properties	Published in Particle and Fibre Toxicology 2009 6:29	2009	The focus of this paper and review is to discuss the present knowledge on physicochemical properties of wood smoke particles from different combustion conditions in relation to wood smoke-induced health effects. In addition, the human wood smoke exposure in developed countries is explored in order to identify the particle characteristics that are relevant for experimental studies of wood smoke-induced health effects. Recent experimental studies regarding wood smoke exposure are discussed with respect to the applied combustion conditions and particle properties
0	Cavanagh JE	Ambient concentrations of polycyclic aromatic hydrocarbons (PAH's) in Christchurch 2008/2009. Report No. 12/?	Prepared by Landcare Research for Environment Canterbury	2012	

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Relevance	Author	Title	Organisation publishing	Date of pub.	Focus of information
0	Cavanagh JE	Ambient concentrations of polycyclic aromatic hydrocarbons (PAH's) in Timaru. Report No. R08/ISBN	Prepared by Landcare Research for Environment Canterbury	2009	Polycyclic aromatic hydrocarbons (PAHs) are ubiquitous air contaminants, primarily derived from incomplete combustion of organic materials. Exposure to ambient-air PAHs may lead to cancer, as well as other detrimental health effects. As part of a larger study on sources of $PM_{2.5}$ in Timaru, a monitoring programme was undertaken to measure concentrations of polycyclic aromatic hydrocarbons (PAHs) and other organic compounds, including alkanes, hopanes and steranes.
0	Cavanagh JE	Ambient concentrations of polycyclic aromatic hydrocarbons (PAH's) in Christchurch 2008-09. Report No. R08/ISBN	Prepared by Landcare Research for Environment Canterbury	2009	Polycyclic aromatic hydrocarbons (PAHs) are ubiquitous air contaminants, primarily derived from incomplete combustion of organic materials. Exposure to ambient-air PAHs may lead to cancer, as well as other detrimental health effects. As part of a larger study on key sources of particulates in Christchurch air, a monitoring programme was undertaken to measure concentrations of PAHs.
0	Cavanagh JE., Trought K., Sheehan T	Toxicity of ambient air samples collected in Timaru over winter 2010	Prepared by Landcare Research for Environment Canterbury	2010	The study aimed to assess the toxicity of the organic fraction of ambient air particulates collected from Timaru over the winter of 2010 by examining: mutagenicity; ethosy resorufin-o-deethylase (EROD) activity as a measure of induction of CYP1A1; cytotoxicity. Chemical (PAH) analysis of the organic fraction was also undertaken
0	Cavanagh JE., Brown L., Trought K., Kingham S., Epton MJ	Elevated concentrations of 1-hydroxypyrene in schoolchildren during winter in Christchurch New Zealand	Landcare Research, University of Canterbury, University of Otago. Published in Science of the Total Environment 374 (2007) 51-59	2007	Polycyclic aromatic hydrocarbons (PAH's)are a key component of airborne particulate matter (PM) and urinary 1-hydroxypyrene (1-OHP) has previously been used to assess exposure of people to PAH's. Research examined urinary 1-OHP in Christchurch male non-smoking schoolchildren (12-18 years) on two occasions after high pollution events. The increased urinary 1-OHP concentrations following nights of elevated particulate concentrations in ambient air suggest increased exposure to ambient air pollution during winter time and could potentially be used as a biomarker of exposure in this population
0	Cavanagh JE., Trought K., Brown L., Duggan S	Exploratory investigation of the chemical characteristics and relative toxicity of ambient air particulates from two NZ cities	Landcare Research - Published in Science of the Total Environment Volume 407, Issue 18, Pages 5007-5018	2009	Paper examining the chemical composition and biological response associated with particulate emissions from the two largest cities in New Zealand, Auckland and Christchurch. Preliminary apportionment of the biological responses to the dominant sources of PM in both cities–wood burners and vehicles–was undertaken

NAQWG – Research Strategy for Air Quality Management

Relevance	Author	Title	Organisation publishing	Date of pub.	Focus of information
5	Cavangah JE., Davy P., Ancelet T., Wilton E	Beyond PM$_{10}$: Benzo(a)pyrene and As concentrations in New Zealand	Published in Air Quality and Climate Change Volume 46 No 2 May 2012	2012	Initial monitoring indicates that benzo(a)pyrene (BaP) and As levels in ambient air in New Zealand notably exceed national and international guidelines and standards. This paper discusses potential sources, the need for a greater regulatory focus be given to these air pollutents and the urgency for management
2	Corsmeier U., Kossmann M., Kalthoff., Sturman A	Temporal evolution of winter smog within a nocturnal boundary layer, Christchurch New Zealand	Published in Meteorology and Atmospheric Physics Volume 91, Numbers 1-4 (2006) 129-148	2006	Paper reports on the Christchurch Air Pollution Study and the establishment of a comprehensive data set for documentation and analysis of nocturnal winter smog conditions in the Christchurch area.
0	Davy P., Day P	Petone-Seaview ambient air quality monitoring strategy 2001-2003	Greater Wellington Regional Council Publication No WRC/RINV-T-01/40	2001	
0	Epton M et al	The effect of ambient air pollution on respiratory health of school children: a panel study	Published in Environmental Health 2008 Volume 7 Issue 16	2008	Adverse respiratory effects of particulate air pollution have been identified by epidemiological studies. We aimed to examine the health effects of ambient particulate air pollution from wood burning on school-age students in Christchurch, New Zealand, and to explore the utility of urine and exhaled breath condensate biomarkers of exposure in this population.
0	Emission Impossible	Air pollution health effects for Wellington Air sheds	Prepared by Emission Impossible for Greater Wellington Regional Council	2011	
4	Fisher GW., Graham BW., Bell MJ	Design of a National Ambient Air Quality Monitoring Network for New Zealand. Environmental Performance Indicators - Technical Paper No. 2 Air	Ministry for the Environment	1995	This study provides the first step in the design and implementation of a national network for monitoring air pollution in NZ. The study defines the requirements for the network

Relevance	Author	Title	Organisation publishing	Date of pub.	Focus of information
1	Fisher G., et al	Health and Air Pollution in NZ - Christchurch Pilot study	Health Research Council of NZ (HAPINZ), Ministry for the Environment and Ministry for Transport	2005	This study is concerned with identifying and quantifying the health risks due to peoples exposure to air pollution. The aim of this study is to explicitly identify the effects of air pollution throughout NZ and to link these effects to the various sources of air pollution and to provide information that will help to formulate effective policy options that lead to real and measureable improvements in the health of New Zealanders. This report documents a pilot study conducted in Christchurch
8	Fisher G., Kjellstorm T., Kingham S., Hales S., Shrestha R	Health and Air Pollution in NZ	Health Research Council of NZ (HAPINZ), Ministry for the Environment and Ministry for Transport	2007	This study is concerned with identifying and quantifying the health risks due to peoples' exposure to air pollution. The aim of this study is to explicitly identify the effects of air pollution throughout NZ and to link these effects to the various sources of air pollution and to provide information that will help to formulate effective policy options that lead to real and measureable improvements in the health of New Zealanders
	Kuschel G, Metcalfe J, Wilton E et al	Updated Health and Air Pollution in NZ	Health Research Council of NZ (HAPINZ), Ministry for the Environment, Ministry for Transport and NZ Transport Agency	2012	Air pollution health effects in New Zealand were first comprehensively assessed in the Health and Air Pollution in New Zealand (HAPINZ) study undertaken by Fisher *et al.* (2007). In this original study, health effects were evaluated for 67 urban areas based on the 2001 population and ambient monitoring data. The resulting social costs were presented in NZ$ as at June 2004. The authors estimated that air pollution from all sources in New Zealand was responsible for approximately 1,400 premature deaths per year, of which 1,100 premature deaths were attributed to anthropogenic (human-caused) sources. Since the release of the original HAPINZ study, both the data availability and the understanding of air pollution health effects have improved. In particular, air quality monitoring is now undertaken in most urban locations in New Zealand – largely in response to the introduction of a national environmental standard for ambient PM_{10} concentrations in September 2005. This report was commissioned to update the original study and is based on existing published work (detailed below), as new research was not conducted for this update: ● population data taken from the 2006 census ● recent monitoring, inventory and source apportionment data collected across New Zealand covering (or representing) ambient PM_{10}

Relevance	Author	Title	Organisation publishing	Date of pub.	Focus of information
					concentrations experienced in 2006 (averaged over 2006-2008) • recent epidemiological results for the main health impacts of air pollution exposure for key population sub-groups, e.g. Māori and children, as well as for the whole population and • updated social costs (in NZ\$ as at June 2010), particularly the use of a transport risk (road safety) based value of a statistical life (VOSL), but not including any loss of life quality due to prolonged pain and suffering.
5	Fisher GW et al	Health effects due to motor vehicle air pollution in New Zealand	Prepared by NIWA, Kevin Rolfe and Assoc, University of Auckland, Wellington Medical School and University of Canterbury for Ministry of Transport	2002	MoT commissioned this study in order to assess the health effects due to air pollution emissions from vehicles on the population of NZ. Based on methodologies established overseas and focused on PM_{10}. Includes an analysis of the relevance of overseas research to NZ
0	Fukuda K., Hider PN., Epton MJ et al	Including viral infection data supports an association between particulate pollution and respiratory admissions	Australian and New Zealand Journal of Public Health Volume 35 Issue 2, Pages 163-169	2010	
0	Gains Wilson J., Kingham S., Pearce J	Air pollution and restricted activity days among New Zealand School children and staff	University of Texas, University of Canterbury and University of Edinburgh. Published in International Journal of Environment and Pollution 2010 Vol 41, No 1/2 pp 140-154	2010	Particulate Matter (PM) air pollution has been associated with a variety of adverse health effects. However, the influence of exposure to particulate pollution on non-notifiable health outcomes such as individual-level restricted activity is less well understood. Days absent from work or school were collected for 2257 students and teachers at eight secondary schools in Christchurch, New Zealand. The results presented in this paper suggest that there is a positive association between restricted activity and particulate matter air pollution even though the associations were not consistently statistically significant.

Relevance	Author	Title	Organisation publishing	Date of pub.	Focus of information
0	Gaines Wilson J., Kingham S., Pearce J., Sturman A	A review of intraurban variations in particulate air pollution - implications for epidemiological research	University of Canterbury. Published in Atmospheric Environment Volume 39 Issue 34, 2005, pp 6444-6462	2005	Epidemiological studies typically utilise one or few central monitoring stations as a proxy for personal exposure to particulate matter air pollution. However, recent research indicates that central monitoring sites may not accurately characterize the spatial complexities of the particulate field across an urban area. Consequently, intraurban assessment of exposure to air pollution has become a priority area of study. This paper reviews particulate air pollution exposure studies with a focus on monitored-data studies at the intraurban spatial scale.
0	Gimson N., Chilton R., Xie, S	Development of meteorological data sets for dispersion modelling. Meteorological Datasets for the Auckland Region - User Guide. Auckland Regional Council Technical Report 2010/022	Golder Associates for Auckland Regional Council	2010	A suite of meteorological datasets have been produced for commonly used air dispersion models in the Auckland region, covering major industrial areas and transport corridors. It is expected that the datasets will be used for air quality assessments of industrial or transport projects in the Auckland Region. This document provides a user guide on these datasets
0	Gimson N., Olivares G., Khan B and Zawar-Reza P	Dispersion Modelling in New Zealand - Part 1 - Assessment of Meteorological models	Prepared by Golder Associates, NIWA and University of Canterbury for FRST	2007	The main aim of this report is to provide advice for practitioners on running the models TAPM and CALMET, assessing their performance and producing meteorological fields for dispersion modelling. Work carried out as part of FRST "Protecting New Zealand's Clean Air" programme
0	Griffiths G	An updated climatology of the Wellington region for air quality purposes. Report No AKL 2011/025	Prepared by NIWA for Greater Wellington Regional Council	2011	
0	Gunatilaka M	Hazardous air pollutants - concentrations of Benzene, Toulene, Ethylbenzene and Xylene (BTEX) in Christchurch 2001/2002. Report No R03/9	Environment Canterbury	2003	An investigation to determine concentrations of benzene, toulene, ethylbenzene and xylene (BTEX) was designed and implemented in May 2001 for a period of one year. Investigation intended to determine annual average concentrations of BTEX, understand seasonal variations and also identify trends of BTEX concentrations in Christchurch
0	Gunatilaka M	Investigations of street level monitoring of carbon monoxide in Christchurch (1993-2001). Report No U02/66	Environment Canterbury	2002	Report summarising CO street level monitoring 1991-2001. Interprets the data and makes recommendations for further monitoring

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Relevance	Author	Title	Organisation publishing	Date of pub.	Focus of information
0	Gunatilaka M	Results of hazardous Air Pollutant monitoring in Christchurch Report R01/31	Environment Canterbury	2001	Report summarises results of monitoring programmes for Christchurch for ply-aromatic hydrocarbons, volatile organic compounds and organochlorines. Source analysis is also undertaken
2	Hales,S., Salmond C., Ian Town G., Kjellstrom T., Woodward A	Daily mortality in relation to weather and air pollution in Christchurch New Zealand	Published in Australian and New Zealand Journal of Public Health. Volume 24, Issue 1, Pages 89-91	2000	To investigate the relationship between the daily number of deaths, weather and ambient air pollution.
0	Holland K., Kingham S	Nitrogen Dioxide exposure inside and outside of Primary Schools	Prepared by University of Canterbury. Published in Epidemiology Volume 19 Issue 6 pp S240-S241	2008	Spatial studies of air pollution and health often assume personal pollution exposure is based on estimated pollution values at the home address. However increasingly we are aware that in many cases people are exposed to very high levels of pollution in places where they may spend less time than at home, but which may actually contribute a greater proportion of an individual's total daily air pollution dose. It should be noted that in New Zealand there is currently a great deal of public and government debate over the levels of pollution in/or near schools and pre-schools, following a recommendation by the local Medical Officer to not allow a daycare centre to open because of poor air quality. This debate is now focusing on how to assess the 'safety' of schools and pre-schools in relation to air quality.
1	King DNT., Wilton E., Bluett J., Gimson NR, Fisher GW	Gap analysis: Enhancing PM_{10} emissions inventories in New Zealand	Prepared by NIWA, Environet and Endpoint for FRST	2005	The purpose of this report is to detail gaps and limitations in current methods and to provide recommendations for improving the quality of inventory data collected. The report also outlines the methodology used to provide basic emission estimates for PM_{10} in NZ at the spatial resolution of census area units
0	Kingham S	How important is urban air pollution as a health hazard?	Editorial published in the New Zealand Medical Journal Vol 124, No 1330 March 2011	2011	Recent research has started to examine the issue of toxicity of different source particles and the findings are inconclusive with some suggesting that biomass/wood smoke does have an effect while others such as Clark et al have not identified a relationship. This paper further examines this issue and concludes with pollution exposure in micro environments requires further attention in future studies
3	Kingham S., Dorset W	Assessment of exposure approaches in air pollution and health research in Australia and New Zealand	Published in Air quality and Climate Change Volume 45 Issue 2	2011	It is increasingly acknowledged that the quality of, and/or lack of, exposure data are often a weakness in studies examining links between air quality and health. In this paper we review studies of air pollution and health in Australia and New Zealand and assess the quality of exposure data used.

Relevance	Author	Title	Organisation publishing	Date of pub.	Focus of information
2	Kingham S., Fisher GW., Hales S., de Lima I., Bartie P	An empirical model for estimating census unit population exposure in areas lacking quality monitoring	Prepared by University of Canterbury and others. Published in Journal of Exposure Science and Environmental Epidemiology Volume 18, Issue 2 pp 200-210	2008	This study presents the methods and results of part of the HAPiNZ (Health and Air Pollution in New Zealand) study. A part of this project was to produce accurate measures of pollution exposure for the entire population of New Zealand living in urban areas. Suitable data are limited in most parts of New Zealand with some areas having no monitoring at all. As a result, this project has developed an empirical model to estimate annual exposure values for the whole country down to the census area unit level. This uses surrogate emission indicators and meteorological variables. Data sources used include census data on domestic heating, industrial emissions estimates, vehicle kilometres travelled and meteorological measurements. These were used to calculate annual exposure estimates and were then compared to monitored data for the areas where monitoring data were available. Results show a good association between the model estimates and the monitored data, enabling advanced health effects assessments for the country's entire urban population.
0	Kingham S., Longley I., Salmond J., Pattinson W., Shrestha K	Determination of personal exposure to traffic pollution while travelling by different modes	Prepared by University of Canterbury and NIWA for New Zealand Transport Agency	2011	The purpose of this project is to assess the comparative risk associated with exposure to traffic pollution when travelling via different transport modes in New Zealand cities. The research objectives were to: provide an accurate measure of personal pollution exposure by mode; provide information for transport decision-making at personal and societal levels; provide a stronger base for advocating a change in consumer behaviour
0	Kingham S., Pearce J., Richardson E	A Geographical approach to assessing the contribution of domestic wood smoke PM_{10} to respiratory and cardiovascular mortality	Published in Epidemiology Volume 22, Issue 1 pp S186-S187	2011	
0	Kingham S., Durand M., Aberkane., Harrison J., Epton M	Winter comparison of TEOM, MiniVol and DustTrak PM10 monitors in a wood smoke environment	Prepared by University of Canterbury and Christchurch School of Medicine and Health Services. Published in Atmospheric Environment Volume 40, Issue 2,	2006	This paper compares PM_{10} mass concentrations data generated by three co-located particulate monitors, the tapered element oscillating microbalance ($TEOM_{40}$) (operating at 40 °C), MiniVol and DustTrak, operating outdoors during winter wood smoke air pollution (Christchurch, New Zealand). Consistent over-recording by the DustTrak and under-recording by the $TEOM_{40}$ were consistent with previously published work. The MiniVol did not correlate well with other instruments (r^2=0.62 and 0.53 against the $_{adj}TEOM_{40}$ and DustTrak, respectively) but reasons for this cannot be ascertained.

Relevance	Author	Title	Organisation publishing	Date of pub.	Focus of information
			January 2006 pp 338-347		
0	Lucas V	Concentrations of benzene, toulene, ethylbenzene and xylene in ambient air, Christchurch and Timaru 2008/09	Environment Canterbury Report No 09/61	2009	
0	Lucas V	Modelling wintertime concentrations of PM10 in ambient air, Christchurch and Timaru.	Environment Canterbury Report No R12/?	2012	
0	McCauley M	Ambient concentrations of polycyclic aromatic hydrocarbons and dioxins/furans in Christchurch 2003/04	Environment Canterbury Report No R03/09	2005a	
0	McCauley M	Concentrations of benzene, toulene, ethylbenzene and xylene in ambient air, Christchurch 2004/5	Environment Canterbury Report No R05/21	2005b	
3	McGowan JA., Hider PN., Chacko E., Town GI	Particulate air pollution and hospital admissions in Christchurch, New Zealand	University of Canterbury, University of Otago. Published in Australian and New Zealand Journal of Public Health, Volume 26, Issue 1 pp 23-29 2002	2002	Winter air pollution in Christchurch is dominated by particulate matter from solid fuel domestic heating. The aim of the study was to explore the relationship between particulate air pollution and admissions to hospital with cardio-respiratory illnesses.

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0	Marsh C., Wilkins AH	An alternative measure of air quality	Environment Canterbury Report U04/76	2004	
9	Ministry for the Environment	Good Practice Guide for Air Quality Monitoring and Data management 2009	Ministry for the Environment	2009	This report provides guidance to help achieve accurate and representative ambient air quality monitoring, using nationally consistent monitoring methods and reporting formats. This guide also aims to make air quality monitoring information accessible by being a quick reference of methods and new developments
8	Ministry for the Environment	Good Practice Guide for preparing Emissions Inventories	Ministry for the Environment	2001	This report is a step by step guide to preparing emission inventories in NZ. It contains information on the purpose, process, methodology and application of emission inventory investigations in NZ. It aims to help those commissioning and participating in emission inventories to produce quality documents with useable information
7	Ministry for the Environment	Air Quality (Four Pollutants) - Environmental Report Card - May 2010 - INFO 487	Ministry for the Environment	2010	This report card tracks air quality against national standards and guidelines that set acceptable levels for key pollutants.
7	Ministry for the Environment	Air Quality (Particulate matter - PM10) - Environmental Report Card - February 2009 - INFO 363	Ministry for the Environment	2009	This report card tracks air quality against national standards and guidelines that set acceptable levels for PM10.
5	Ministry for the Environment	Health effects of CO, NO2, SO2, Ozone, Benzene and Benzo(a)pyrene in New Zealand. Air Quality Technical Report No 43 - AQTR 43	Prepared by Environet Ltd for Ministry for the Environment	2003	This report considers health effects literature in the context of concentrations of carbon monoxide (CO), nitrogen oxides (Nox, sulphur dioxide (SO2), ozone, benzene and benzo(a)pyrene (BaP) currently measured in NZ. The purpose of this report is to provide an indication of the extent to which existing concentrations of air contaminants in NZ may compromise health.
5	Ministry for the Environment	Health effects of PM_{10} in New Zealand - AQTR 39	Prepared by Environet Ltd for Ministry for the Environment	2003	This technical report comprises a review of the health implications of PM10 concentrations in New Zealand and provides an overview of the existing knowledge on the health impacts of particle pollution
3	New Zealand Transport Agency	Ambient air quality (nitrogen dioxide) monitoring network report 2007-2009	New Zealand Transport Agency	2009	This report describes the features of the NZTA national NO2 passive monitoring network and reviews data gathered from the beginning of 2007 up to the end of 2008. Results are compared spatially and temporally

Relevance	Author	Title	Organisation publishing	Date of pub.	Focus of information
3	Olivares G., Smith J., Bluett J	The development of a mobile monitoring system to investigate the spatial variation of air pollution - NIWA client report CHC2008-091	Prepared for NIWA for FRST	2008	This report describes the system developed by NIWA for assessing spatial variability of airborne particulate matter concentrations; demonstrates the utility and application of data collected by the system; makes recommendations for improvements to the system
0	Richardson EA., Pearce J., Kingham S	Is particulate air pollution associated with health and health inequalities in New Zealand	Prepared by University of Edinburgh and University of Canterbury. Published in Health and Place Volume 17, Issue 5, September 2011 pp 1137-1143	2011	Air pollution can increase mortality risk and may also exacerbate socioeconomic inequalities in health outcomes. This New Zealand study investigated whether exposure to particulate air pollution (PM_{10}) was associated with mortality and health inequalities. Annual mean PM_{10} estimates for urban Census Area Units (CAUs) were linked to cause-specific mortality data. A dose-response relationship was found between PM_{10} and respiratory disease mortality, including at concentrations below the existing annual average guideline value of 20 µg m^{-3}. Establishing and enforcing a lower guideline value is likely to have population health benefits. However, socioeconomic inequalities in respiratory disease mortality were not significantly elevated with PM_{10} exposure.
0	Sabel CE., Gaines Wilson J., Kingham S., Tisch C., Epton M	Spatial implications of covariate adjustment on patterns of risk: respiratory hospital admission in Christchurch, New Zealand	Published in Social Science Medicine Volume 65, Issue 1, Pages 43-59	2007	Epidemiological studies that examine the relationship between environmental exposures and health often address other determinants of health that may influence the relationship being studied by adjusting for these factors as covariates. While disease surveillance methods routinely control for covariates such as deprivation, there has been limited investigative work on the spatial movement of risk at the intraurban scale due to the adjustment. It is important that the nature of any spatial relocation be well understood as a relocation to areas of increased risk may also introduce additional localised factors that influence the exposure-response relationship. This paper examines the spatial patterns of relative risk and clusters of hospitalisations based on an illustrative small-area example from Christchurch, New Zealand.
0	Sabel CE., Wilson JG., Kingham S., Tisch C., Epton M	Spatial implications of covariate adjustment on patterns of risk: respiratory hospital admissions in Christchurch, New Zealand	Published in Epidemiology 19, 6, s110	2008	
0	Scarrott C	Statistical calibration of PM10 concentrations	Environment Canterbury	2012	

Relev ance	Author	Title	Organisation publishing	Date of pub.	Focus of information
		within Canterbury Airsheds			
0	Scoggins, A	Does air pollution pose a public health problem for New Zealand?	Published in Australian and New Zealand Journal of Public Health. Volume 28, Issue 1, Pages 16-19	2004	Air pollution is increasingly documented as a threat to public health and a major focus of regulatory activity in developed and developing countries. Air quality indicators suggest New Zealand has clean air relative to many other countries. However, media releases such as 'Christchurch wood fires pump out deadly smog' and 'Vehicle pollution major killer' have sparked public health concern regarding exposure to ambient air pollution, especially in anticipation of increasing emissions and population growth. Recent evidence is presented on the effects of air quality on health, which has been aided by the application of urban air shed models and Geographic Information Systems (GIS). Future directions for research into the effects of air quality on health in New Zealand are discussed,
0	Stevenson C., Hally V., Noonan M., James TI	State of the Environment Report West Coast Ambient Air quality. West Coast Regional Council Ref 0401	West Coast Regional Council	2004	This report provides information on air quality monitoring conducted at Westport, Reefton, Runanga, Greymouth and Hokitika over the period from 2001-03. Parameters measured include PM10, continuous and month sulphur dioxide and monthly volatile organic compounds - benzene, toulene, ethyl-benzene and xylene. A human health risk assessment is provided
0	Sturman A., Titov M., Zawar-Reza P	Selecting optimal monitoring site locations of peak ambient particulate material concentrations using the MM5-CAMx4 numerical modelling system	Prepared by the University of Canterbury and Aurecon Ltd. Published in Science of the Total Environment 409 (4): pp810-821	2011	Installation of temporary or long term monitoring sites is expensive, so it is important to rationally identify potential locations that will achieve the requirements of regional air quality management strategies. A simple, but effective, numerical approach to selecting ambient particulate matter (PM) monitoring site locations has therefore been developed using the MM5-CAMx4 air pollution dispersion modelling system. This method of assessing the appropriateness of any potential monitoring site can be used to optimize monitoring site locations for any air pollution measurement programme.

Relev ance	Author	Title	Organisation publishing	Date of pub.	Focus of information
0	Sturman A., Zawar-Reza P	Application of back-trajectory techniques to the delimitation of a Clean Air Zone for the Christchurch air shed. Report prepared by Centre for Atmospheric Research, University of Canterbury for Ecan. Environment Canterbury Report No U01/24	Canterbury Regional Council	2000	
0	Titov M., Sturman A., Zawar-Reza P	Improvement of predicted fine and total particulate matter (PM) composition by applying several different chemical scenarios: A winter 2005 case study	Prepared by University of Canterbury. Published in Science of the Total Environment Volume 385 Issues 1-3 October 2007. pp 284-296	2007	A new method using several different chemical scenarios is developed to predict chemical composition of fine ($PM_{2.5}$) and total (PM_{10}) aerosol. This method improves the accuracy of predicted PM concentrations. The Mesoscale Model version 5 (MM5) and a 3-dimensional Eulerian chemical model (CAMx4.2) are used to predict $PM_{2.5}$ and PM_{10} concentrations using gridded input emissions (from the "Total" group) over a 48–72 h time period for Christchurch (New Zealand) for winter 2005. The chemical composition of the modelled $PM_{2.5}$ is also discussed.
0	Wilson JG., Kingham S., Pearce J., Sturman AP	A review of intraurban variations in particulate air pollution: implications for epidemiological research	Prepared by University of Canterbury. Published in Atmospheric Environment Volume 39, Issue 34 pp 6444-6462	2005	Epidemiological studies typically utilise one or few central monitoring stations as a proxy for personal exposure to particulate matter air pollution. However, recent research indicates that central monitoring sites may not accurately characterize the spatial complexities of the particulate field across an urban area. Consequently, intraurban assessment of exposure to air pollution has become a priority area of study. This paper reviews particulate air pollution exposure studies with a focus on monitored-data studies at the intraurban spatial scale.
0	Wilson JG., Kingham S., Pearce J	Air pollution and restricted activity days among New Zealand school children and staff	International Journal of Environment and Pollution. Volume 41 Issue 1-2, Pages 140-154	2010	

Relevance	Author	Title	Organisation publishing	Date of pub.	Focus of information
0	Wilton E	Recalculation of the number of restricted activity days that may be associated with particulate concentrations in Christchurch. Unpublished report No. U01/56	Canterbury Regional Council	2001a	
0	Wilton E	Assessment of the health benefits associated with management options to reduce PM10 concentrations in Christchurch. Unpublished Report No U01/87	Canterbury Regional Council	2001b	
0	Wilton EV	Update: The health effects of suspended particulate. Report No U99/51	Canterbury Regional Council	1999	
0	Zawar-Reza P	A dispersion modelling analysis of tropospheric ozone potential for Canterbury - Report No U05/73. Prepared for Environment Canterbury	University of Canterbury	2005	A report outlining the methodology for preparation of a spatial map of tropospheric ozone concentrations in the Canterbury Region - sources of emissions are from Christchurch
2	Zawar-Reza P., Sturman A., Hurley P	Prognostic Urban-scale air pollution modelling in Australia and New Zealand - a review	Prepared by University of Canterbury. Published in Clean Air and Environmental Quality Volume 39, Issue 2 pp41-45	2005	This paper reviews research conducted in the past two decades in urban-scale air quality modelling in Australia and New Zealand, with emphasis on prognostic models. With advances in computer technology - especially desktop computers - air pollution dispersion modelling is now a feasible undertaking not only for well funded research institutions, but also for air quality consultants.

12.3 RESPONSE

Relevance	Author	Title	Organisation publishing	Date of publ.	Focus of information

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0	Appelhans T et al	Using air quality data to track progress toward PM10 standards: Case study - Christchurch 1999-2006. NIWA Client Report CHC2007-135	Prepared by NIWA for FRST	2007	This report details research that has been undertaken to investigate in detail the complex relationship between emissions, weather and PM10 concentrations. The analysis has been conducted on monitoring data from central Christchurch over the 8 year period 1999-2006. Christchurch was chosen because ECan has operated an active series of mitigation policies and it was postulated that the analysis could help determine how effective these have been
0	Barna MG., Gimson NR	Dispersion Modelling of a wintertime particulate pollution episode in Christchurch, New Zealand	Published in Atmospheric Environment (2002), Volume 36, Issue 21 pp 3531-3544	2002	This paper examines the inter-suburb dispersion of particulate air pollution in Christchurch, New Zealand, during a wintertime particulate pollution episode. The dispersion is simulated using the RAMS/CALMET/CALPUFF modelling system, with data from a detailed emissions inventory of home heating, motor vehicles and industry. Three emission reduction options, designed to reduce the severity of particulate pollution episodes in Christchurch, are simulated. When both domestic open-hearth fires and all coal burning are removed, the 24h average peak concentration is reduced by 55%. The number of guideline exceedances of PM10 in the modelled period is reduced from five to one. Removing open-hearth fires results in 42% reduction in PM_{10} concentration, resulting in three exceedances of the guideline, and removing coal-burning fires yields a 32% reduction in PM10, resulting in four exceedances of the guideline.
2	Barns S	Cost Effectiveness of Policy Options for Air Quality Management in Tokoroa. Waikato Regional Council Technical Report TR2008/23	Waikato Regional Council	2008	Policy options addressing this problem, including regulations and incentives, were analysed for cost effectiveness (heating, health and productivity losses) on the basis of daily and winter emissions. Under regulatory policies it is generally the user who pays, in contrast to incentive policies which may be government funded. This dichotomy is addressed by measuring policy acceptance by the community. Policy acceptance probabilities were estimated from two surveys of representative stakeholder groups. The permutations of 36 individual factors for each policy were analysed using a decision support tool developed for this project
0	Baynes M., Cavanagh JE., Wilton E	Communications strategy for air quality in the Hawkes Bay Region. Landcare Research Contract Report LC0910/027	Prepared by Landcare Research for the Hawkes Bay Regional Council - Envirolink Project No 757-HBRC109	2009	
0	Bicknell KB	Synopsis of Literature Benefits of Reducing Air Pollution.	Canterbury Regional Council	1997	

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Relevance	Author	Title	Organisation publishing	Date of publ.	Focus of information
0	Cavanagh JE	Potential of vegetation to mitigate road-generated air pollution Part 1 - review of background information	Prepared by NIWA - Public Report - Reviewed by NES Research advisory group. Part of FRST "Protecting New Zealand's Clean Air"	2005	The objectives of this current report are to review the existing literature to assess different design strategies (spacing, width, plant types etc) of vegetation buffers to improve air quality
0	Cavanagh JE	Options to reduce particulate matter emissions in New Zealand: Retrofits to home heating and vehicles	Landcare Research Contract report LC0607/123 - prepared under MSI contract C01X0405	2007	
0	Cavanagh JE	Influence of Urban Trees on Air Quality in Christchurch: Preliminary estimates - Contract Report LC0708/097	Prepared for Christchurch City Council by Landcare Research	2008	This research undertakes a study to investigate the influence of urban trees on air quality in Christchurch between November 2007 and March 2008. The aim of the work is to provide preliminary estimates of pollutant removal (PM_{10}, NO2, O3, SO2, CO by urban trees in Christchurch
0	Cavanagh JE., Clemons J	Do trees enhance air quality?	Landcare Research contract report LC0203/0148	2003	
0	Cavanagh JE., Clemons J	Do Urban Forests Enhance Air Quality	Landcare Research published in Australasian Journal of Environmental Management, Volume 13	2006	This article is a review of the current science behind how urban trees influence the level of ambient air pollutants that exist in common urban air sheds
0	Cavanagh JE., Zawar-Reza P., Gaines Wilson J	Spatial attenuation of ambient particulate matter air pollution within an urbanised native forest patch	Landcare Research, University of Canterbury, University of Texas. Published in Urban Forestry and Urban Greening 8 (2009) 21-30	2008	Of interest to researchers and urban planners is the effect of urban forests on concentrations of ambient air pollution. Although estimates of the attenuation effect of urban vegetation on levels of air pollution have been put forward, there have been few monitored data on small-scale changes within forests, especially in urban forest patches. This study explores the spatial attenuation of particulate matter air pollution less than PM10 within the confines of an evergreen broadleaved urban forest patch in Christchurch

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3	Environmental Protection Authority of New South Wales, Australia	Guidelines for estimating chimney heights for small to medium sized fuel burning equipment	Environmental Protection Authority of New South Wales, Australia	1993	
0	Fisher G	Health, Safety and Environment Guide for the Boatbuilding Industry - Section 6.3 Cleaner Air	Developed by Endpoint Consultancy	2004	Paper prepared for the Boat Building industry highlighting health issues within this industry from various practices. Offers advice to mitigate and minimise effects
3	Fisher G., Kuschel G., Mahon K	Straight and Curved Line Paths (SLiPs and CLiPs) - developing the targets and predicting the compliance. Discussion, methodology and example - a report to regional councils	NIWA - Part of FRST "Protecting New Zealand's Clean Air"	2005	This discussion document outlines some of the key issues that should be considered by Regional Council's when developing SLiPs or CLiPs when assessing compliance with the NES Air Quality in 2005 and beyond
3	Fisher GW	Significant and Principal Source - NES Implementation and Good Practice Guides - concept development and discussion		2006	This document provides concept development and discussion regarding the interpretation of phrases within the amended NES regulations (a principal source and increase significantly). The paper discusses the implementation of the NES and good practice guides
0	Fisher G., Petersen J	Implications of reducing Wintertime Air Pollution in Christchurch on Greenhouse Gas Emissions - Report No U01/84. Prepared by NIWA for Environment Canterbury	Canterbury Regional Council	2001	This document addresses air pollution and examines the question - "Are we doing the right things to protect and improve the air - both the local air quality and our global atmosphere and climate?". The purpose of this document is to try and define in broad, but quantitative terms just what is known now, and what is likely to happen in the next 20 years
3	Fisher GW., Sherman M	Climate trends and air pollution: Is an outlook possible?	Prepared by Endpoint Consulting partners for Meteorological Society of NZ 23-25 November 2005	2005	Presentation outlining the requirements of the NES and the difficulties in achieving the new targets

Relevance	Author	Title	Organisation publishing	Date of publ.	Focus of information
0	Fisher G., Peterson J	Christchurch City: Managing Local and Global Air Pollution. Environment Canterbury Report No U01/84	Canterbury Regional Council	2001	
1	Gimson NR., Zawar-Reza P., Xie S., Revell M	Straight line paths and urban air shed modelling	Public report reviewed by NES Research Advisory Group - Part of FRST "Protecting New Zealand's Clean Air"	2005	This report demonstrates methodologies for using predictive air shed models as tools in the determination of straight-line paths to compliance with the National Environmental Standards. It is shown that the relationship between PM_{10} concentration and emission rate can be considered linear and this relationship is exploited to make predictions of future PM10 levels under prescribed emissions reduction scenarios
0	Greer G., Bicknell K	Updated economic analysis of options to reduce suspended particulate from domestic burning in Christchurch.	Canterbury Regional Council	2001	
0	Kuschel G., Bluett J	Stocktake of Transport Related Air Pollution (TRAP) Research in New Zealand	Prepared by Emission Impossible and NIWA for New Zealand Transport Agency	2010	Objective of this report is to take the first step towards answering "what applied research needs to be funded to better manage the air quality impacts of transport in NZ?". Report undertakes a stocktake of relevant applied research to date, both in NZ and overseas; identifies critical knowledge gaps where current understanding is unable to adequately address key transport objects and recommends priorities for future end-user research funding
0	Lucas V	Meeting the National Environmental Standard for PM_{10} in Timaru, Washdyke and Geraldine - an update. Report No R08/90	Environment Canterbury	2008	
0	Mallett T., Scott A	Options for setting particulate emissions criteria for home heating appliances. Environment Canterbury Report No. R02/28	Environment Canterbury	2002	Information presented to Environment Canterbury Council regarding the Clean Heat project. Discusses the establishment of criteria by which the emissions performance of different appliances can be compared and the approaches available. This report sets out the issues that need to be considered in defining criteria that might be used to distinguish between appliances for the purpose of managing emissions
0	Mallett T	Is Christchurch likely to meet the NESAQ targets for PM_{10}?	Environment Canterbury Report No R12/40	2012	

Relevance	Author	Title	Organisation publishing	Date of publ.	Focus of information
7	Ministry for the Environment	Good Practice Guide for Assessing and Managing Odour in New Zealand - ME473	Ministry for the Environment	2003	This guide suggests a national approach to assessing and managing offensive odours. It contains well-debated, expert advice for those involved in managing odour. Includes advice on assessment of effects, monitoring effects, case law, when to use dispersion modelling and how to manage odour emissions
9	Ministry for the Environment	Good practice guide for assessing and managing the environmental effects of dust emissions - ME408	Ministry for the Environment	2001	This guide aims to provide useful information and recommendations on how to assess and manage the environmental effects of particle or dust emissions from sources such as quarrying etc. Includes assistance in: assessing environmental effects, developing regional air plans, considering resource consents, preparing district plans, compliance monitoring and State of the Environment Monitoring
8	Ministry for the Environment	Good practice guide for monitoring and management of visibility in New Zealand	Ministry for the Environment	2001	This guide describes the nature of visibility, degradation by air pollution and why efforts should be made to preserve and maintain good visibility conditions. The guide discusses the value of visibility, what contaminants degrade visibility and their sources, describes monitoring methods, processes for visibility management and legislative framework and outlines ways in which visibility can be improved or protected
3	Ministry for the Environment (prepared by NIWA and others for the Ministry for the Environment)	Visibility in New Zealand - National Risk Assessment - AQTR 18	Ministry for the Environment	2000	This report presents preliminary work to examine the potential development of a visibility risk index for NZ.
5	Ministry for the Environment (prepared by Taylor Baines and Associates for MFE)	Warm Homes Technical Report: Social Drivers - Phase 2 Report - ME706	Ministry for the Environment	2005	Warm homes project has been set up by MFE to examine ways to encourage NZ households to move to cleaner heating sources and increase household energy efficiency and overall to achieve warmer and healthier homes. One key aspect of this work has been to investigate the social drivers behind householders decisions on home heating, insulation and appliance choice. Phase 2 of this work involves analysing issues and options for programme design, holding workshops in 4 communities and developing the concept of a national programme

Relevance	Author	Title	Organisation publishing	Date of publ.	Focus of information
5	Ministry for the Environment (prepared by Taylor Baines and Associates for MFE)	Warm Homes Technical Report: Social Drivers - Phase 1 Report - ME702	Ministry for the Environment	2005	Warm homes project has been set up by MFE to examine ways to encourage NZ households to move to cleaner heating sources and increase household energy efficiency and overall to achieve warmer and healthier homes. One key aspect of this work has been to investigate the social drivers behind householders decisions on home heating, insulation and appliance choice. Phase 1 focused on providing a comprehensive scoping of what is already known about the social drivers. It covers a review of literature and extensive discussions with over 30 key practitioners and experts in this area.
7	Ministry for the Environment (prepared by Tracy Freeman and Roger Cudmore for MFE)	Review of Odour Management in New Zealand - Technical Report AQTR 24	Ministry for the Environment	2002	This report was commissioned to provide detailed background and technical information and recommendations for the MFE review of Odour Management under the RMA. The aim is for this report to become the primary reference document for the revised odour guide.
0	Moores J., Pattinson P., Reed J., McHugh M, Cavanagh JE	Mitigation Strategies for Controlling the Dispersion of Particulate Metals Emitted from vehicles	NIWA and others - funded by FRST	2008	This report describes the findings of research into the effectiveness of a number of mitigation strategies employed to reduce the contamination of receiving environments with metals originating from road vehicles. Aim of research was: establish the recent historical impact of vehicle derived metals (specifically zinc and copper) in a drainage catchment by investigating the dispersion, deposition and accumulation of these metals in the environment; establish the relative importance of dispersion pathways be estimating the loads of these metals transported by air-borne and water-borne routes; evaluate the effectiveness of mitigation strategies designed to intercept dispersion of particulate metals along the alternative pathways
1	O'Connell MJ., Gaudin MR., Kirk LE	The Clean Heat Project: Improving Air Quality and Energy Efficiency outcomes for the Canterbury Region	Prepared by Environment Canterbury. Published in Air Quality and Climate Change Volume 44 Issue 2 (May 2010)	2010	This paper discusses primarily the processes, challenges and outcomes of the Clean Heat Project; and secondly, the links to central government air quality and energy (efficiency) policy and initiatives.

Relevance	Author	Title	Organisation publishing	Date of publ.	Focus of information
0	Pearce J., Kingham S	Environmental inequalities in New Zealand: A national study of air pollution and environmental justice	Prepared by University of Canterbury. Published in Geoforum Volume 39, Issue 2, March 2008	2008	In this New Zealand research we use mean annual estimates of outdoor particulate air pollution for different sources for neighbourhoods across urban New Zealand to evaluate whether air pollution varies between local areas of differing socioeconomic circumstances. The results are discussed in the context of the policy framework in New Zealand, including the tensions fashioned by the Resource Management Act 1991, which have effectively 'desocialised' environmental concerns. We argue that the regulatory framework is fixated on 'environmental bottom lines' rather than social concerns that are integral to the environmental justice framework. Some priorities for future research into environmental justice in New Zealand are also considered.
0	Pearce J., Kingham S., Zawar-Reza P	Every breath you take? Environmental justice and air pollution in Christchurch New Zealand	Published in Environment and Planning, 2006, Volume 38 (5) pp 919-938	2006	In this paper we use accurate and geographically detailed estimates of pollution calculated from an atmospheric dispersion model to examine issues of environmental justice related to air pollution sourced from domestic heating in Christchurch, New Zealand, a city with particularly high levels of particulate pollution during winter months. We consider whether there is a social gradient in exposure to air pollution in Christchurch by comparing estimates of particulate pollution for small areas across the city to a range of demographic and socioeconomic indicators including age, ethnicity, income, and deprivation. Furthermore, we examine whether there is a social gradient in exposure to extreme pollution episodes. We demonstrate that different social groups in the Christchurch population are exposed to different levels of both ambient air pollution and extreme air-pollution episodes. In particular, pollution is significantly higher among more disadvantaged communities. We also find evidence which suggests that the groups responsible for producing a large proportion of the pollution in Christchurch are not the same groups exposed to high levels of particulate air pollution.
3	Scarrott Dr C., Reale Dr M., Newell Dr J	Statistical estimation and testing of trends in PM_{10} concentrations: Is Christchurch city likely to meet the NES target for PM_{10} concentrations in 2013? Report No. R09/27	Prepared for Environment Canterbury by University of Canterbury	2009	The aim of this study is to use the information in the hourly PM_{10} measurements to identify and estimate any trends in the PM_{10} concentrations, and in particular the exceedances of the target level in 2013. The statistical significance of any estimated trends in the PM10 concentrations and in particular the exceedances of the target level in 2013. The statistical significance of any estimated trends will also help provide evidence as to whether existing PM10 reduction strategies have been effective and highlight possible needs for further reductions strategies to ensure this target is met
0	Scarrott C	Statistical estimation and testing of trends in PM_{10} concentrations: - addendum 1 - update for	Environment Canterbury	2009	

Relevance	Author	Title	Organisation publishing	Date of publ.	Focus of information
		2008 Report No. R09/27 Addendum 1			
0	Scott A., McCauley M.	Meeting the National Environmental Standard for PM10 in Kaiapoi and Rangiora. Report No R08/36	Environment Canterbury	2008	This report presents the results of an "emission forecast" for Kaiapoi and Rangiora. It predicts changes in air quality out to 2013 and beyond under a number of different management scenarios. The report which focuses on PM10 only is intended to facilitate discussion on the broader policies that may be considered for improving air quality in both towns rather than dictate the path to compliance
0	Scott A., McCauley M., Lucas V	Meeting the National Environmental Standard for PM_{10} in Asburton - updated. Report No R08/34	Environment Canterbury	2008	
0	Scott AJ	Reducing concentrations of suspended particulate (PM_{10}) in Timaru - An assessment of possible management measures. Environment Canterbury Report No U02/40	Canterbury Regional Council	2002	
0	Scott A	Impact of air quality targets on residential heating emissions in Christchurch - revised	Environment Canterbury Report No U05/80	2005b	
0	Scott A	Impact of air quality strategies on residential heating emissions in Christchurch - an update	Environment Canterbury Report No U05/18	2005c	
0	Scott AJ., Scarrott C	Impacts of residential heating intervention measures on air quality and progress towards targets in Christchurch and Timaru, New Zealand	Prepared by Environment Canterbury and University of Canterbury. Published in	2011	This paper presents the results of a partial accountability analysis where the impact of management actions and measures are measured against the reduction in PM_{10} and the probability of meeting air quality targets.

Relevance	Author	Title	Organisation publishing	Date of publ.	Focus of information
			Atmospheric Environment 45 (2011) 2972-2980		
5	Sherman M., Fisher G	Relationship between average and peak PM$_{10}$ concentrations : The New Zealand experience	Endpoint Ltd - Published in Clean Air and Environmental Quality Volume 41 Issue 2 (2007)	2007	Using almost all the PM$_{10}$ monitoring data from NZ available for periods of more than four years, a study has been made of the relationship between the annual mean concentration and the peak daily value at each site upon which the NES is based. There is a strong and well defined linear relationship between the mean and peak values at most sites. The nature of this relationship implies that policies and methods used to reduce daily peaks will have a defined and identifiable reduction in the annual averages.
0	Sinclair Knight Merz	Performance Criteria for Air Pollution Control Equipment. Report prepared by Sinclair Knight Merz for Auckland Regional Council	Auckland Regional Council	2000	This report was commissioned by the Auckland Regional Council to aid development of the air quality chapters for the Regional Plan. It aims to discuss the application of air pollution control equipment to activities that may be subject to rules in this Plan. Current design and performance criteria are presented for the most common control equipment along with suggested activities most suited to their use
0	Sinclair Knight Merz	Assessing Risk from Potential Air Discharges Following Industrial Incidents. Prepared by Sinclair Knight Merz for Auckland Regional Council	Auckland Regional Council	2000	This report was commissioned to progress the production of guidance for those submitting applications for discharges to air. It is a discussion document written as part of the process of developing the Regional Plan. This report focuses on the potential effects of air discharges from industrial incidents, since such discharges present a risk that currently may not be fully considered during applications for Resource Consents
1	Spronken-Smith RA., Sturman AP., Wilton EV	The Air pollution problem in Christchurch, New Zealand - progress and prospects	Prepared by University of Canterbury and Environet Ltd. Published in Clean Air and Environmental Quality Volume 36, Issue 1	2002	Christchurch has had a wintertime air pollution problem for much of the last century. In the first half of the century the main pollutants were sulphur dioxide and suspended particulate matter, while in recent years suspended particulate matter and carbon monoxide have exceeded ambient air quality guidelines many times each winter. This paper reviews progress made in understanding and managing the air pollution problem and then considers prospects of further improving air quality through research and management.

Relevance	Author	Title	Organisation publishing	Date of publ.	Focus of information
0	Taylor Baines and Associates	Assessment of the likely social impacts resulting from the proposed domestic heating rules contained in the Air quality chapter of the Natural Resources Regional Plan. Environment Canterbury Unpublished Report No U01/83	Canterbury Regional Council	2001	
2	Wilton E	Management options for reducing PM_{10} concentrations in Blenheim - Update 2009	Prepared by Environet Ltd for Marlborough District Council	2009	Report updating a 2007 report on the effectiveness of management options in reducing PM_{10} concentrations in Blenheim. This update includes a revision of the emission factor for NES compliant wood burners. Report evaluates a number of management options
0	Wilton E., Anderson B., Iseli J	Cost effectiveness of policy options for boilers - Ashburton,	Environment Canterbury - Report No U07/94	2007	This report evaluates the costs and the effectiveness of setting emission limits for industrial boilers in reducing PM10 emissions in Ashburton.
0	Wilton E., Anderson B., Iseli J	Cost effectiveness of policy options for boilers - Christchurch	Environment Canterbury - Report No U07/95	2007	This report evaluates the costs and the effectiveness of setting emission limits for industrial boilers in reducing PM10 emissions in Christchurch.
0	Wilton E., Anderson B., Iseli J	Cost effectiveness of policy options for boilers - Kaiapoi	Environment Canterbury - Report No U07/96	2007	This report evaluates the costs and the effectiveness of setting emission limits for industrial boilers in reducing PM10 emissions in Kaiapoi.
2	Wilton E., Anderson B., Iseli J	Cost effectiveness of policy options for boilers - Rangiora	Environment Canterbury - Report No U07/97	2007	This report evaluates the costs and the effectiveness of setting emission limits for industrial boilers in reducing PM10 emissions in Rangiora.
0	Wilton E., Anderson B., Iseli J	Cost effectiveness of policy options for boilers - Timaru	Environment Canterbury - Report No U07/98	2007	This report evaluates the costs and the effectiveness of setting emission limits for industrial boilers in reducing PM10 emissions in Timaru.
0	Wilton E., Anderson B., Iseli J	Cost effectiveness of policy options for boilers - Washdyke	Environment Canterbury - Report No U07/99	2007	This report evaluates the costs and the effectiveness of setting emission limits for industrial boilers in reducing PM10 emissions in Washdyke.
2	Wilton E., Baynes M	Management of PM10 in Masterton, Upper Hutt and Wainuiomata.	Prepared by Environet Ltd for Greater Wellington Regional Council	2008b	

Relevance	Author	Title	Organisation publishing	Date of publ.	Focus of information
4	Wilton E., Bluett J	Exploring the impact of regulations on PM_{10} concentrations in six urban air sheds in New Zealand	Prepared by Environet Ltd and NIWA. Published in Air Quality and Climate Change Volume 46 Issue 1 (February 2012)	2012	Concentrations of PM10 regularly exceed the New Zealand National Environmental Standard (NES) of 50 mug m-3 (24-hour average) in many urban air sheds of New Zealand (MfE 2010). In some air sheds the issue is being addressed through the introduction and implementation of regulations targeting the main source of these breaches, solid fuel burning from domestic heating. In other areas emissions from domestic heating remain un-regulated. This paper provides a review of progress toward attainment the NES within six urban air sheds of New Zealand. The aim of the paper is to evaluate changes in PM_{10} concentrations over time and compare these to emissions projections and emission inventories in six urban air sheds in New Zealand.
5	Wilton E., Cavanagh JE	Inter-relationships between air quality, energy efficiency, housing, health and climate change in relation to the use of wood burners for domestic home heating	Prepared by Environet Ltd and Landcare Research. Published in Air Quality and Climate Change Volume 46 No.2 May 2012	2012	Paper discussing regulations in NZ, reducing emissions from domestic home heating and the opportunity for greater benefits to be achieved if inherent links to energy efficiency, warm homes and climate change mitigation are considered.
1	Wilton E	Hamilton, Taupo, Te Kuiti and Tokoroa: an assessment of management options to achieve National Environmental Standards. Waikato Regional Council Technical Report TR2007/15	Prepared by Environet Ltd for Waikato Regional Council	2007	The impact of management options to reduce PM_{10} concentrations in Taupo, Te Kuiti, Hamilton and Tokoroa are examined in this report. Results suggest that the NES is unlikely to be met in any area without additional measures. A combination of incentives and regulations is likely to be required in all locations.
0	Wilton E	Management options for air quality in Hamilton and Te Kuiti: An assessment of management options to achieve National Environmental Standards. Waikato Regional Council Technical Report TR2005/53	Prepared by Environet Ltd for Waikato Regional Council	2005	The impact of management options to reduce PM_{10} concentrations in Hamilton and Te Kuiti is examined in this report for measures targeting domestic heating and outdoor burning. Results suggest that the implementation of the NES design standard for wood burners may be sufficient to achieve the NES in both areas, although additional measures are recommended if a higher degree of certainty is required.

Relevance	Author	Title	Organisation publishing	Date of publ.	Focus of information
0	Wilton E	Health Impacts of PM10 pollution in Hamilton, Tokoroa, Te Kuiti and Taupo: an assessment of the Health benefits of management options to reduce PM10. Waikato Regional Council Technical Report TR 2005/54	Prepared by Environet Ltd for Waikato Regional Council	2005	An evaluation of management options to reduce PM_{10} concentrations has been carried out for Hamilton, Tokoroa, Te Kuiti and Taupo. This indicates a range of measures for achieving reductions in each location and an indication of the impact on PM_{10} concentrations relative to the NES for PM_{10}. This report evaluates some of the health benefits of these management options in each location.
0	Wilton E	Estimates of the effectiveness of management options for reducing PM10 concentrations in Christchurch. Environment Canterbury Unpublished Report No U01/87	Canterbury Regional Council	2001c	
0	Wilton E., Baynes, M	Improving PM_{10} Emission Factors from Industrial Boilers in New Zealand - Stage 2			
0	Wilton E., Gurnsey P	Variations to the air quality target for Christchurch and the associated impact on wood burner numbers. Environment Canterbury Unpublished Report No U01/87	Canterbury Regional Council	2001	
7	Wright J	Feedback to the Ministry for the Environment on the Proposed Changes to the NES for Air Quality PM_{10}. Report from the Parliamentary Commissioner for the Environment	Prepared by the Parliamentary Commissioner for the Environment	2010	With the aims of reviewing the PM10 standard, the Minister for the Environment appointed a Technical Advisory Group (TAG) who produced a detailed report in November 2009. Based on the TAG report, the Ministry in June 2010 released a document proposing changes to the PM10 standard and requested public feedback. This submission is in response to that request.

NAQWG – Research Strategy for Air Quality Management

Relevance	Author	Title	Organisation publishing	Date of publ.	Focus of information
4	Xie S., Bluett JG., Fisher GW., Kuschel GI., Steadman DH	On-road Remote Sensing of Vehicle Exhaust Emissions in Auckland, New Zealand	Prepared by NIWA, Endpoint Ltd, Auckland Regional Council and University of Denver. Published in Clean Air and Environmental Quality, Volume 39, Issue 4 (2005)	2005	In order to inform policy and increase understanding of air pollution effects, there is a requirement for more information on the emissions of NZ's vehicle fleet. This remote sensing campaign was implemented to establish the emissions profile for the on-road vehicle fleet. The data has been used to investigate the important factors that determine the fleet emission profiles.
0	Zawar-Reza P., Sturman A	Application of air shed modelling to the implementation of the New Zealand National Environmental Standards for Air Quality	Prepared by University of Canterbury. Published in Atmospheric Environment Volume 42 Issue 38 pp 8785-8794	2008	The main objective of this study is to assess the efficacy of the emission reduction strategy implemented by Environment Canterbury (the local air quality management authority) for the city of Christchurch using an air pollution model called TAPM. Results show that the 2013 emission inventory will cause no exceedances at the location of the monitoring station in Christchurch. However, due to the complex wind regime and topography of the area, it is highly likely that the NES will be exceeded at locations away from the monitoring site, making Christchurch non-compliant with its objectives. This is particularly significant as the NES apply to the maximum concentration occurring anywhere in the polluted air shed.

12.4 Standards/Guidelines

Relevance	Author	Title	Organisation publishing	Date of publ.	Focus of information
3	European Union	EU Directive 2008/50/EC - Ambient air quality and cleaner air for Europe	Official Journal of the European Union - 11 June 2008	2008	Paper provides insight into legislative drivers in Europe – directive for various contaminants, and consistent monitoring requirements for member states.
3	European Union	EU Directive 2004/107/EC - Relating to arsenic, cadmium, mercury, nickel and polycyclic aromatic hydrocarbons in ambient air	Official Journal of the European Union - 26 January 2005	2008	Legislation establishing the need to reduce pollution to levels which minimise harmful effects on human health, paying particular attention to sensitive populations and the environment as a whole. Discusses monitoring of arsenic, cadmium, nickel and polycyclic aromatic hydrocarbons and the setting of targets
2	Fisher GW., King DNT., Bluett J., Gimson NR., Wilton E., Xie S., Faulk M., Cudmore R., Kingham S., Sturman AP., Ladd M	Defining New Zealand's air sheds: Local Air Management Areas (LAMAs)	Public report reviewed by NES Research Advisory Group	2005	In September 2005, regional councils and unitary authorities identified 42 areas where air quality could reach levels higher than the national air quality standards. These areas are called air sheds. Document was the precursor to these air sheds being gazetted
6	Ministry for the Environment	MfE Clean Healthy Air for All New Zealanders: The National Air Quality Compliance Strategy to Meet the PM_{10} Standard - ME1064	Ministry for the Environment	2011	The Compliance strategy has been developed to ensure NZ meets the ambient PM_{10} 24 hour standard set by the RMA (NES for air quality) Regulations 2004. It sets out the practices that regional councils could adopt to meet the standard for PM_{10} and thereby deliver clean health air for all New Zealanders
8	Ministry for the Environment	2011 Users Guide to the revised National Environmental Standards for Air Quality - ME1068	Ministry for the Environment	2011	Purpose of the guide is to provide practitioners with their "first Port of call" assistance in interpretation and implementation of the Resource Management (NES for Air Quality) Regulations 2004 including the 2011 amendments. It seeks to assist practitioners to apply the Regulations in a streamlined and consistent manner across New Zealand and consequently deliver clean healthy air to all New Zealanders sooner

Relevance	Author	Title	Organisation publishing	Date of publ.	Focus of information
8	Ministry for the Environment	Revised National Environmental Standards for Air Quality: Evaluation under Section 32 of the RMA - ME1041	Ministry for the Environment		This document presents an analysis of the amendments made to the NES for Air Quality in 2010 and the addition of non-regulatory instruments.
8	Ministry for the Environment	Proposed Amendments to the National Environmental Standards for Air Quality - Report on Submissions - ME1037	Ministry for the Environment	2011	This report provides information on the review of the NES for Air Quality and includes information on: the Technical Advisory Group for Air Quality; proposed amendments to the standards,; summary of submissions and list of submitters
4	Ministry for the Environment	Regulatory Impact Statement: Amending the PM_{10} Air Quality Standards: Final Recommendations	Ministry for the Environment	2010	This statement analyses the costs and benefits of proposed amendments to the PM10 regulations contained within the NES for Air Quality
2	Ministry for the Environment	Proposed Amendments to the National Environmental Standards for Air Quality - discussion document - ME1018	Ministry for the Environment	2009/10?	This discussion document no longer available online - see ME1037 for summary of submissions to this original discussion document
5	Ministry for the Environment	Report of the Technical Advisory Group on National Air Quality standards - CR90	Ministry for the Environment	2009	A report prepared by the TAG to review current regulations surrounding the PM_{10} standards within the NES Air Quality. The TAG's report is to be an input in to a Ministerial review of the PM_{10} regulations
6	Ministry for the Environment	Ambient Air Quality Guidelines - Updated 2002	Ministry for the Environment	2002	This report contains new ambient air quality guideline values for NZ and updated guidance on how they should be used to manage air quality under the RMA. These new guidelines replace those first published by MFE in 1994.
0	NZIER	The value of air quality standards: Review and update of cost benefit analysis of National Environmental Standards on air quality	Ministry for the Environment	2009	This report is an update on the cost benefit analysis undertaken in 2004 of the NES air quality that underpinned the Section 32 Assessment for introducing the standards

Relevance	Author	Title	Organisation publishing	Date of publ.	Focus of information
9	United States Environmental Protection Authority	Air and Radiation home page for US EPA. Multiple links to Air Quality issues, contaminants and management	US EPA		United States Environmental Protection Agency - Air and Radiation homepage - multiple links to various air quality topics / issues/ contaminants
0	Wilton E, Baynes M., Cavanagh JE	Guidance document for preparing an air quality monitoring report	Report prepared for West Coast Regional Council. Envirolink Project No 710-WCRC65	2009	
0	Wilton E, Baynes M., Cavanagh JE	Instructions for estimating the impact of changes in fuel types for Richmond using the "tracking changes" air quality management tool. Landcare Research Contract Report LC0910/095	Prepared by Landcare Research for Tasman District Council. Envirolink Project No 756-TDC54	2010	
2	Wilton E., Baynes M., Bluett J	Good practice guide for designing and Implementing an Incentives Programme for Domestic Heating	Prepared by Environet and NIWA under Envirolink Tools project number NIWX0802	2008	This report if part of the Envirolink funded "Developing a Cost Effective air Quality Incentives Programme Toolkit". This guide together with the spatial model (available at http://wrenz.niwa.co.nz/webmodel/emissions) and cost model (**was on NIWA website originally however link unable to be found**) provide a complete toolkit to enable councils to develop cost effective incentives programmes to reduce PM10 concentrations in their communities
5	World Health Organization	Air quality Guidelines - global update 2005. Particulate matter, ozone, nitrogen dioxide and sulphur dioxide	World Health Organization	2005	The WHO air quality guidelines offer guidance on reducing the effects on health of air pollution. This guideline presents revised guideline values for the four most common air pollutants based on a recent review of the accumulated scientific evidence.

12.5 Proceedings

Relevance	Author	Title	Organisation publishing	Reference	Date of publ.
0	Appelhans T	An air pollution climatology for Christchurch, New Zealand		7th International Conference on Urban Climate, Yokohama, Japan, 29 June - 3 July 2009	2009
0	Appelhans T	Trends in atmospheric controls on PM_{10}		New Zealand Marine Sciences and Meteorological Societies Joint Conference, Auckland New Zealand - 2nd to 4th September 2009	2009
0	Appelhans T., Sturman A., Zawar-Reza P	Modelling emission trends from non-constant time series of PM_{10} concentrations in Christchurch, New Zealand		International Journal of Environment and Pollution. Volume 43 Issue 4, Pages 354-363	2010
0	Ayrey R., Kingham S	Air pollution issues and solutions - 1965 to 2004, Christchurch		Symposium proceedings - Canterbury Regional Symposium September 2004	2004
4	Bluett J., Wilton E., Ponder-Sutton A	Assessing Long-Term Trends in PM_{10} concentrations - Nelson, New Zealand		Conference proceedings 19th International Clean Air and Environment Conference. 6th - 9th September 2009, Perth, Western Australia	2009
3	Bluett JG	A validation of AUSPLUME in a multiple point source industrial estate		Conference proceedings 14th Clean Air and Environment pp 564-70	1998
0	Coulson G., Longley I., Pattinson W., Kingham S., Reddish L., Olivares G	Street-to-street variations in PM, PNC and BC in a motorway dominated urban neighbourhood		Conference proceedings European Aerosol Conference (EAC2011) 4-9th September 2011, Manchester UK	2011
1	Davy P., Markwitz A., Trompetter WJ	Source characterisation of air particulate emissions from a road tunnel in Wellington New Zealand	GNS	Reviewed proceedings of the 16th International Clean Air and Environment Conference, 18-22 August 2002, Christchurch New Zealand	2002
4	Davy P., Markwitz A., Trompetter WJ	Elemental analysis and source apportionment of ambient particulate matter in the Wellington region of New Zealand	GNS	Reviewed proceedings of the 16th International Clean Air and Environment Conference, 18-22 August 2002, Christchurch New Zealand	2002
2	Davy P., Markwitz A., Trompetter WJ	Elemental analysis and source apportionment of ambient particulate matter in Masterton, New Zealand	GNS	International Journal of PIXE, Volume 15, Nos 3-4 (2005) pp 225-231	2005
2	Davy P., Markwitz A., Trompetter WJ., Weatherburn DC	Elemental analysis and source apportionment of ambient particulate matter at an industrial area of Wellington, New Zealand	GNS	13th World Clean Air and Environmental Protection Congress and Exhibition 22-27 August 2004, London UK	2004

0	Davy PK, Markwitz A., Weatherburn DC	Comparison of wood smoke particles from source emissions and in urban air by SEM-EDS	GNS	In proceedings of the 14th International Union of Air pollution prevention and environmental protection associations (IUAPPA) World Congress 2007, 18th Clean Air Society of Australia and NZ Conference	2007
0	Dirks K., Longley I., Salmond J., Kingham S	Blood carboxyhaemoglobin levels as a biomarker for urban air pollution exposure		Conference proceedings 9th International Conference on Southern Hemisphere Meteorology and Oceanography 9-13 February 2009, Melbourne Australia	2009
3	EECA - Energy Efficiency and Conservation authority	Guidance for local authorities PM_{10} emissions from wood fuels	EECA	This document sets out to provide a source of information to local authorities to assist them when considering both regulatory provisions in plans and individual application for resource consent for discharge to air.	2012
0	Khan BA., Zawar-Reza P., Sturman A	Effect of the sea breeze on air pollution in the Auckland Region, New Zealand		7th International Conference on Air Quality - Science and Application, Istanbul, 24-27 March 2009	2009
0	Kingham S	Mortality from air pollution in New Zealand: a preliminary analysis	University of Canterbury	Conference contribution - oral presentation - 10th International symposium in medical geography 14-18 July 2003, Manchester UK	2003
0	Kingham S., Brown M., Pearce J., Day P	Assessing the health effects of pollution exposure in a small town: the case of Reefton, New Zealand		18th Australasian Epidemiological Association Annual Scientific Meeting 30 August - 1 September 2009, Dunedin, New Zealand	2009
3	Kingham S., Brown M., Pearce J., Day P	An assessment of the health effects of domestic coal sourced particulate pollution in a small town		20th International Clean Air and Environment Conference (CASANZ 2011) 31 July - 2 August 2011	2009
0	Kingham S., Pattison W., Longley I., Salmond J	Traffic exposure and modal choice: A New Zealand case study.		Proceedings of the Joint Conference of International Society of Exposure Science/International Society for Environmental Epidemiology. Seoul, August 28-September 01 2010	2010
0	Kingham S., Pearce J., Zawar-Reza P	Who breathes in the dirtiest air and who causes it? Traffic pollution and poverty in New Zealand		Conference proceedings Environment and Transport 2nd International Scientific Symposium 12-14th June 2006	2006
1	Kingham S., Pearce J., Zawar-Reza P	An estimation of pollution exposure for small spatial units in Christchurch New Zealand		Conference proceedings 17th International Clean Air and Environment Conference 3-6 May 2005, Hobart, Australia	2005
1	Kingham S., Richardson E., Pearce J	The relative contribution of domestic and traffic sources of PM_{10} to cause-specific mortality		Conference proceedings 20th International Clean Air and Environment Conference (CASANZ 2011) 31 July - 2 August 2011	2011

0	Longley I., Olivares G., Harper S., Kingham S., Pattinson W., Dirks K	A multi-method assessment of the impact of road traffic on local air quality in Auckland		Conference proceedings 20th International Clean Air and Environment Conference 31 July - 2 August 2011, Auckland New Zealand	2011
0	Longley I., Pattinson W., Talbot N., Kingham S	Exposure to ultrafine and light-scattering particles at suburban schools with contrasting traffic influence, including travel to and from school		Conference proceedings International Society of Exposure Science 21st Annual Meeting 23-27 October 2011	2011
0	Longley I., Shrestha K., Kingham S., Salmond J., Pattinson W	Statistical distributions of particle number concentrations observed in urban transport microenvironments during commuting.		Conference proceedings - European Aerosol Conference (EAC1011) 4-9 September 2011	2011
0	Longley ID	What is sustainable air quality?		Proceedings of the 4th International Conference on Sustainability Engineering and Science, Auckland NZ November 30 - December 3 2010	2010
0	Longley ID, Hosking J., Peters J	Air Quality and Early Childhood Centres in Auckland		Public Health Association of NZ Conference in Dunedin, September 2009	2009
3	Longley ID, Olivares G., Coulson GF., Talbot N	Experimental observations of in-vehicle exposure to particles in real-world driving		European Aerosol Conference, Karlsruhe, Germany 6-11 September 2009	2009
0	Longley ID., Coulson G., Olivares G	Healthy urban Atmospheres (HUA) - Observational Studies from Year One of New Zealand's exposure research programme		Proceedings of "Air Pollution and Health: Bridging the Gap from Sources to Health Outcomes". San Diego March 2010	2010
0	Longley ID., Harper S., Olivares G., Talbot N., Coulson G	"Observing and modelling particle number concentrations inside vehicles in busy traffic"		Proceedings of the 8th International Aerosol Conference - Helsinki August 29 - September 3 2010	2010
1	Olivares G., Bluett J	Measuring Spatial variation of Winter particulate Air Pollution in Taupo, New Zealand		19th International Clean Air and Environment Conference. 6th - 9th September 2009, Perth, Western Australia	2009
0	Olivares G., Smith J., Bluett J., Coulson G	Spatial Variation and characterisation of Ambient Aerosols from Domestic Solid Fuel Burning in a New Zealand Town		Advanced Atmospheric Aerosol Seminar - Naples 9-12 November 2008	2008
0	Olivares G., Smith J., Bluett J., Zawar-Reza P	Mobile Black Carbon Measurements for Source Apportionment in Wood Smoke related Air Pollution Episodes in New Zealand		7th International Conference on Air Quality - Science and Application, Istanbul, 24-27 March 2009	2009
3	Pearce J., Kingham S	Do the poor breathe in poorest quality air? Air pollution and poverty in Christchurch, New Zealand	University of Canterbury	Conference proceedings 17th International Clean Air and Environment Conference 3-6 May 2005, Hobart, Australia	2005

	Authors	Title	Organisation	Source	Year
1	Salmond J., Kingham S., Longley I., Dirks K., Williams D., Wagner J., Henshaw G	3-Dimensional Spatio-Temporal Variability in Air Quality at a road intersection		Conference proceedings CASANZ International Clean Air and Environment conference 6-9th September 2009, Perth Australia	2009
2	Salmond J., Williams D., Laing G., Kingham S., Dirks K., Longley I., Henshaw G	Influence of vegetation on the vertical distribution of pollutants in a street canyon		Conference proceedings 20th International Clean Air and Environment Conference 31 July - 2 August 2011, Auckland New Zealand	2011
0	Scott A	Chemical characterisation and source apportionment of fine particles in Christchurch, New Zealand: Part 1 - modelling by Positive Matrix Factorisation	Environment Canterbury	Proceedings of the 13th World Clean Air and Environmental Protection Congress and Exhibition, London UK, 22-27 August 2004	
0	Sturman AP., Zawar-Reza P., Katurji M	Application of modelling techniques to the investigation of air pollution in small towns in New Zealand		7th International Conference on Air Quality - Science and Application, Istanbul, 24-27 March 2009	2009
2	Trompetter WJ, Markwitz A., Davy P	Air particulate analysis in New Zealand with Ion Beam Analysis: Correlation of elemental fingerprints with meteoric data in the Wellington Region	GNS	Reviewed proceedings of the 15th International Clean Air and Environment Conference, 26-30 November 2000, Sydney Australia	2000
3	Trompetter WJ, Markwitz A., Davy P	Characterisation of Air Particulate Matter from vehicles in New Zealand	GNS	Reviewed proceedings of the 17th International Clean Air and Environment Conference, 6-11 May 2005, Hobart Australia	2005
1	Trompetter WJ, Markwitz A., Davy P	Air particulate research capability at the NZ Ion Beam Analysis Facility using PIXE and IBA techniques	GNS	International Journal of PIXE, Volume 15, Nos 3-4 (2005) pp 249-255	2005
3	Trompetter WJ., Markwitz A., Davy PK., Mitchell T	Ambient air particulate source activity measured with hourly resolution	GNS	Reviewed proceedings of the 18th International Clean Air and Environment Conference and the 14th IUAPPA World Congress, 9-13 September 2007, Brisbane Australia	2007
6	Trompetter WJ., Davy PK., Markwitz A	Temporal variation of PM_{10} during winter nights in New Zealand	GNS	Reviewed proceedings of the 19th International Clean Air and Environment Convergence - 6-9 September 2009, Perth Australia	2009
1	Trompetter WJ., Markwitz A	The GNS Ion Beam Analysis facility plays a key role in the analysis of ambient particulate matter in New Zealand	GNS	Reviewed proceedings of the 16th International Clean Air and Environment Conference, 18-22 August 2002, Christchurch New Zealand	2002

13 Appendix 2: Prioritisation Process

13.1 Prioritisation Process – Known Management Needs

An outline of the prioritisation process is provided in Figure 7.
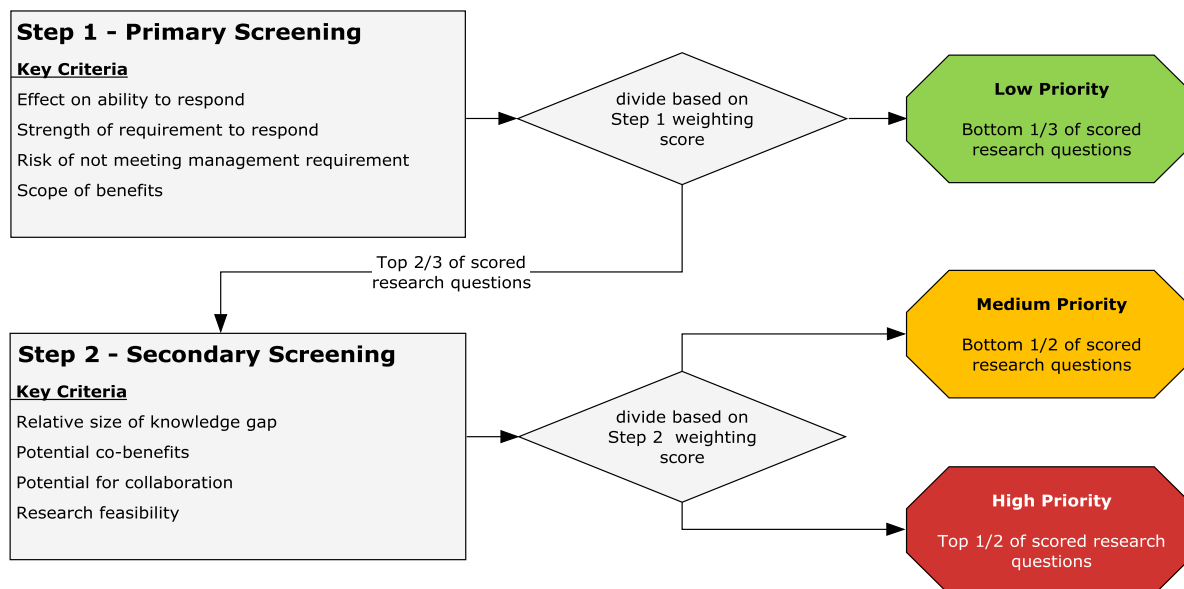
Figure 7: Process Overview - Known Management Needs

13.1.1 Step 1 – Primary Screening

The primary screening process is applied to all research questions that would help meet known management needs. The screening questions and assessment guidance are detailed below.

While working through the prioritisation process refer to both the research question and the management need it addresses when evaluating your answers.

Question 1 - ability to create an improved management response

How much would answering this research question improve your current ability to create a response that would meet the required management need?

	0-25% improvement	25-50% improvement	50% improvement	50-75% improvement	Above 75% improvement
Score	0	10	20	25	30

Assessment guidance:
In this subjective assessment - a 50% score would represent being able to create a response that would be considered half as good again as your current response to that management needs. Note: The applicability this improvement across regions is assessed in Q4.

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Question 2a and 2b - obligation to respond

2a) The research question is related to a known management need – how strong is the requirement (assessed along a spectrum of mandatory to discretionary) to meet this specific management need?

Define specific management requirement: (i.e. meeting NES PM_{10} Standard)

Define the specific management need that this question relates to: (i.e. understanding the sources of PM_{10} and their relative contributions to PM_{10} in an airshed)

Mandatory		→		Discretionary
e.g.	Legislative need (RMA)		Guidelines	Strategy or Non Statutory Plan
e.g.	NES Air Quality	RPS, Regional Plan	Air Quality Guidelines	Long Term Plan	
Score	30	20	10	5	0

Assessment guidance: This requires the subjective assessment of the requirement to respond to a management need. These needs can be driven by one or more requirement (ie: NES and/or Regional Plan. You need to think about what degree of discretion is available as to whether the issue requires management to achieve some standard or outcome.

2b) How soon would answers to the research question be required to meet the specific management need?

	now	1-3 years	3-5 years	5 years +
Score	5	4	2	0

Question 3a and 3b - risk of not meeting management requirement

How significant is the risk (both likelihood and consequence) of not meeting this specific management requirement if this research is not undertaken?

3a) Likelihood of not meeting this specific management requirement

	very low	low	medium	high	very high
Score	0	2	5	8	10

3b) Consequence of not meeting this management requirement

	very low	low	medium	high	very high
Score	0	2	5	8	10

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Risk can be assessed based on the two aspects – likelihood of something occurring and the consequence if it does occur.

For likelihood – an assessment of very high would mean that outcome is almost certain to occur, an assessment of medium would mean ~50% chance of occurring.

For consequence – an assessment of very high would have substantial financial and political costs/implications, an assessment of medium would carry some financial and or political cost/implications, an assessment of low would carry minimal financial or political cost/implications

Question 4 - scope of benefit

Answering this research question would benefit what extent of New Zealand?

	1 Region	2-4 Regions	All Regions
Score	5	10	15

Assessment guidance: The ability of a research question to meet all or some of the information requirements of various Regional Councils.

13.1.2   Step 2 - Secondary Screening

This secondary screening process is then applied to the top scoring 66% of research questions from Step 1 (see Figure 7 for process). Scores for these questions are cumulative from Step 1 (i.e. the scores allocated here are added to those the question gained in Step 1).

Question 1 - size of knowledge gap

What is the extent of existing relevant knowledge for the research question?

	Small (0-10%)	Moderate (10-50%)	Reasonable (50-80%)	Large (80-100%)
Score	30	20	10	0

Assessment guidance: (Note: the research question is focused on a specific management need – so the assessment is defining the extent of relevant knowledge for this management need. 0% nothing known, 100% know enough to develop effective management response)

Question 2 - Co-benefits

Would answering this research question create co-benefits which would help to answer other air quality management needs (either known or emerging)?

	No	Some	Moderate	Significant
Score	0	5	10	20

Assessment guidance: Assess considering both the likelihood of creating a co-benefit and the magnitude of the co-benefit. Therefore consider - how many research needs would this question answer? How large would these co-benefits be? 'Significant' would be assisting two or more other questions with substantial benefits gained.

'Moderate' would be 1 question assisted with substantial benefits, or 2 or more questions with moderate benefits. 'Some' would be 1 question with moderate benefits.

Question 3 - potential for collaboration

What is the potential for collaboration with other councils or researchers to support, fund, and/or undertake research?

	low	medium	high	very high
Score	0	10	20	30

Assessment guidance: The potential to use skills, knowledge and funding from various sources for a project.

Low = no potential – project would be undertaken by one Council with no assistance

Medium = some potential – at least one or two other Council and/or researchers involved

High = good potential – greater than three councils and/or researchers involved

Very high = excellent potential – greater than five councils and/or researchers involved

Question 4a and 4b - research feasibility

4a) What is the relative feasibility of undertaking the research based on factors such as cost, skills and availability?

	very low	low	medium	high	very high
Score	0	2	5	8	10

Assessment guidance:

Low = High costs >$500K and/or restricted skills and availability – potentially skills not available in NZ or limited to one researcher. Limited or only one source of potential funding

Medium = Costs manageable $150 - $500K from one or two sources, 1or 2 researchers skilled/available to undertake work within NZ.

High = Costs lower <$150K, skills readily available from several or multiple researchers and within NZ. Multiple sources of funding available

4b) How long would it take answer this specific research question if funded tomorrow?

	< 1 year	1 years	1-3 years	3-5 years
Score	10	8	5	2

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13.2 Prioritisation Process – Emerging or New Issues

A similar process to that of known management needs is used to assessing new or emerging issues and is outlined in Figure 8
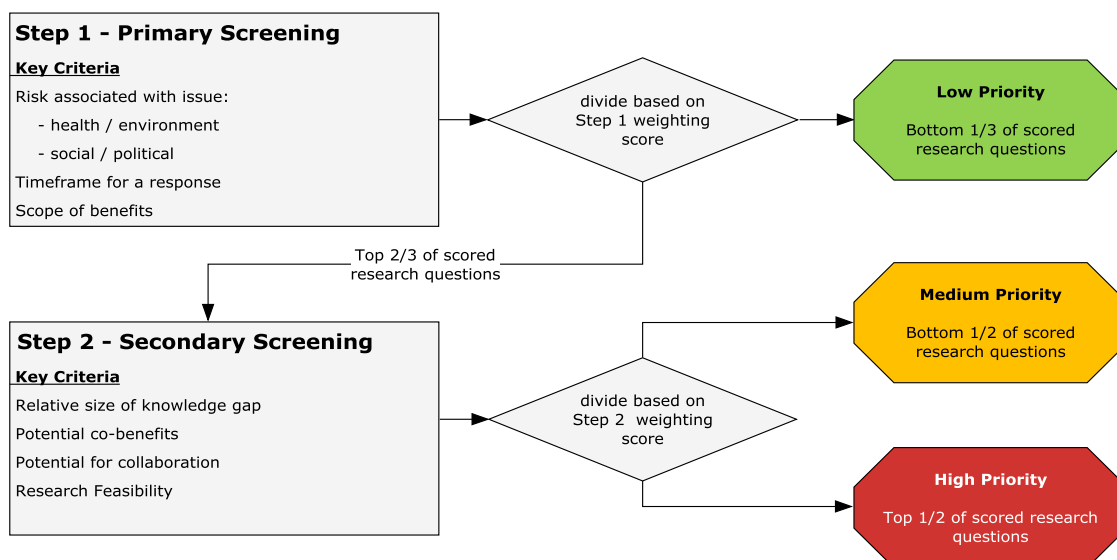
Figure 8: Process Overview - Emerging or New Issues

13.2.1   Step 1 – Primary Screening

The primary screening process is applied to all research questions identified within the emerging and new issues framework (see Figure 8for process). Note that for emerging and new issues the research questions can relate to both the identification and extent of an issue and the understanding and development of management resposnes.

Question 1a, 1b and 1c, 1d – risk and consequence associated with issue

Impact on human health/environment

How significant is the potential risk (both likelihood and consequence) of this issues on human health and/or environment?

1a) Likelihood of human health / environmental impact occurring?

	very low	low	medium	high	very high
Score	0	2	8	15	20

1b) Consequence of this impact on human health /environment?

	very low	low	medium	high	very high
Score	0	2	8	15	20

Assessment guidance: Risk can be assessed based on the two aspects – likelihood of something occurring and the consequence if it does occur.

For likelihood – an assessment of very high would mean the outcome is almost certain to occur, an assessment of medium would mean ~50% chance of occurring.

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For consequence – Should consider both the severity and spatial extent of impact - an assessment of very high would have substantial health and environmental costs/implications, an assessment of medium would carry some health and environmental cost/implications, an assessment of low would carry minimal health and environmental cost/implications

Social/political concern

How significant is the risk (both likelihood and consequence) of community and/or political reaction to this issue if this work is not undertaken?

1c) Likelihood of adverse community/political reaction

	very low	low	medium	high	very high
score	0	2	5	8	10

1d) Consequence of an adverse community/political reaction?

	very low	low	medium	high	very high
score	0	2	5	8	10

Assessment guidance: Risk can be assessed based on the two aspects – likelihood of something occurring and the consequence it if does occur.

For likelihood – an assessment of very high would mean the outcome is almost certain to occur, an assessment of medium would mean ~50% chance of occurring.

For consequence – an assessment of very high would have substantial community and political costs/implications, an assessment of medium would carry some substantial community and political cost/implications, an assessment of low would carry minimal substantial community and political cost/implications

Question 2a and 2b - need to respond in future

2a) What is the likelihood that a formal management requirement, necessitating an effective response for this issue, will emerge in the next planning cycle (~5-10 years)?

	Very Unlikely	Unlikely	50:50	Highly Likely	Almost Certain
Score	0	2	5	8	10

Assessment guidance:

Almost certain = this issue will need to be included into the next review of policy and/or legislation

50:50 = greater than even chance that this issue will need to be included into the next review of policy and/or legislation

Very Unlikely = minimal chance that this issue will need to be included into the next review of policy and/or legislation

2b) How soon would answers to the research question be required to meet this potential planning requirement?

	1 year	1-2 years	3-5 years	5-10 years
Score	10	8	5	2

13.2.2   Step 2 – Secondary Screening

This secondary screening process would be applied to the top scoring 66% of research questions from Step 1 (see Figure 5 for process)

Question 1 - size of knowledge gap

What is the extent of existing relevant knowledge for the research question?

	Small (0-10%)	Moderate (10-50%)	Reasonable (50-80%)	Large (80-100%)
Score	30	20	10	0

Assessment guidance: (Note: the research question is focused on a specific management need – so the assessment is defining the extent of relevant knowledge for this management need. 0% nothing known, 100% know enough to develop an effective management response)

Question 2 - co-benefits

Would answering this research question create co-benefits which would help to answer other management needs (either known or emerging)?

	No	Maybe	Probably	Definitely
Score	0	5	10	20

Assessment guidance: How many research needs would this answer? Would results of this question help to answer part of another research question? Would results assist in other Council activities such as integrated planning?

Question 3 - potential for collaboration

What is the potential for collaboration with other councils or researchers to support, fund, and/or undertake research?

	low	medium	high	very high
Score	0	10	20	30

Assessment guidance: The potential to use skills, knowledge and funding from various sources for a project.

Low = no potential – project would be undertaken by one Council with no assistance

Medium = some potential – at least one or two other Council and/or researchers involved

High = good potential – greater than three councils and/or researchers involved

Very high = excellent potential – greater than five councils and/or researchers involved

Question 4a and 4b - research feasibility

4a) What is the relative feasibility of undertaking the research based on factors such as cost, skills and availability?

	very low	low	medium	high	very high
Score	0	2	5	8	10

Assessment guidance:

Low = High costs >$500K and/or restricted skills and availability – potentially skills not available in NZ or limited to one researcher. Limited or only one source of potential funding

Medium = Costs manageable $150 - $500K from one or two sources, 1or 2 researchers skilled/available to undertake work within NZ.

High = Costs lower <$150K, skills readily available from several or multiple researchers and within NZ. Multiple sources of funding available

4b) How long would it take answer this specific research question if funded tomorrow?

	< 1 year	1 years	1-3 years	3-5 years
Score	10	8	5	2

14 Appendix 3: Research Priorities

14.1 Prioritisation of Broad Research Areas

Domain	Broad level research area	Ranking *	Average**	Auckland	Waikato	Wellington	Canterbury	BOP	Hawkes Bay	Otago	Taranaki	Tasman	West Coast
Pressure Understanding relationships between emissions and air quality	Understanding anthropogenic contributions (emission factors and uncertainty)	3	3.9	5	3	4	4	5	4	3	4	4	3
	Use of dispersion models & meterology information in defining pressure	13	2.8	3	4	3	3	3	4	1	2	3	2
	Understanding the impacts of chemistry and atmospheric processes (inc. secondary particles) on pressures	17	2.4	3	5	2	3	2	3	1	3	1	1
	Source apportionment (inc. natural sources)	9	3.2	4	4	2	3	3	4	2	4	4	2
State Describing & measuring air quality	Quantifying spatial variability of air quality	10	3.1	4	4	5	3	3	3	1	2	3	3
	Information gaps regarding air toxics	15	2.7	4	4	4	2	3	3	1	2	2	2
	Creating affordable monitoring methods	3	3.9	3	2	5	4	3	5	5	5	5	2
	Ensuring quality measurement of Air Quality (national consistency & QA & representativeness)	5	3.7	4	3	4	2	5	3	5	5	2	4
Impact of the State Quantifying effects of air quality	Understanding Human health effects of different air quality states (inc. natural sources & air toxics)	5	3.7	5	4	3	3	3	4	1	5	5	4
	Understanding variability of social susceptibility/consequences of poor air quality (social consequences)	15	2.7	4	3	3	2	4	3	1	3	1	3
	Methods for exposure assessment and management	13	2.8	4	2	3	2	3	3	1	5	3	2
Response- to "Pressure-State" Managing (response) the pressures (emissions) to improve the state (ambient air quality)	Tools and methods for creating scenario assessment to inform responses	12	3.0	4	3	4	2	2	4	4	2	4	1
	How to effectively apply dispersion modelling to define management responses	18	2.3	3	3	2	1	3	3	2	2	3	1
	How to effectively influencing human behaviour & understanding barriers to change	8	3.3	4	3	5	4	4	4	1	5	1	2
	Understanding multi-pollutant management to create integrated responses	10	3.1	4	3	3	3	3	4	1	4	4	2
	Identifying or creating technological solutions to improve air quality	2	4.0	4	3	5	1 #	5	4	5	5	2	3
	Methods or tools to create broader solutions (inter-relationships energy/housing/climate change)	7	3.5	4	3	5	3	4	3	3	3	5	2
Response effect on "Impact" Are responses actually reducing pressures (emissions). Is reduced pressure improving state and is health (impact) improving as a consequence?	Understanding and quantifying the effectiveness of management responses	1	4.6	5	4	5	5	5	4	4	5	5	4

Coding for individual Councils   5 or 4 High
3 or 2 Medium
1 low

* Ranking colour coding is based on top 1/3rd red, 2/3rd orange, bottom 1/3rd green

** Average for responses from 10 councils (See Appendix 16 for details)

interpretation that this is outside our responsibility as councils, there are other funding sources available (other than MSI, envirolink etc) for this type of work.

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14.2 Prioritisation of Research Questions for Known Management Needs

Known Management needs												
Domain/Broad research area	Question	Management need	Average		Auckland	Waikato	Wellington	Canterbury	BOP	Hawkes Bay	Otago	Taranaki
PRESSURE				Note on Colour and Ranking								
Anthropogenic contributions (emission factors and uncertainty)	What are the emission factors for BaP and Benzene from different sources (woodburning and vehicles in particular)?	To facilitate more realistic scenario modelling of the impacts of management strategies for controlling pollutant emissions	11.4		18	17	6	18	1	10	2	19
	What is the range of uncertainty for emission factors, fuel use, appliance age/type profile etc information used in emissions inventories?	To facilitate more realistic scenario modelling of the impacts of management strategies for controlling pollutant emissions.	25.4		15	24	28	25	32	21	33	
Dispersion models & meterology	Are the commonly-used models for air quality management 'fit-for-purpose ' or could other international modelling approaches (e.g. e.g., AERMOD, ADMS-Road) be introduced for New Zealand?	To help ensure emission reduction targets and AEEs based on modelling are credible and defendable	19.4		11	26	31	15	10	25	24	13
	Is there a need to improve meteorological inputs for modelling (to provide robust and easily updated data)?	To help ensure emission modelling uses consistent data to assist credibility.	14.3		4	9	30		11	7	23	16
Impact of chemistry and atmospheric processes (inc. secondary particles)	How important is secondary particulate and what impact will current AQ strategies have on its concentrations?	To allow secondary contributions to be accounted for and managed by targeting precursor emissions if required?	13.9		23	34	5	19	7	8	11	4
	What is happening in the early hours of the morning, and during the winter with regard to chemistry and particle formation?	To understand relationship between precursor emission sources and secondary particles for improving responses.	13.5		19	35	4	23	7	5	11	4
Source apportionment (inc. natural sources)	What is the contribution of natural sources to PM_{10} and $PM_{2.5}$ and what constitutes an exceptional exceedence involving natural sources?	To monitor the effectiveness of measures to reduce anthropogenic emissions by separating out the natural component.	23.8		35	29	10	16	29	19	26	26
	What is the particle size distribution and diurnal profile for natural sources?	To create targeted responses that address manageable sources	17.9		17	31	3	13	29	6	22	22

Known Management needs

Domain/Broad research area	Question	Management need	Average		Auckland	Waikato	Wellington	Canterbury	BOP	Hawkes Bay	Otago	Taranaki
STATE												
Spatial variability	How do PM concentrations (and other pollutants) vary across an airshed and how can we cost effectively predict the location of peak concentrations?	To justify location of monitoring stations for NES-AQ compliances, location specific management or for other purposes.	20.1		16	36	36	11	12	16	27	7
Information gaps re air toxics (eg, BaP, PAH) & PM2.5	Are there non-NES contaminants (e.g. BaP, As, formaldehyde) that we should be measuring and comparing with compare with NZ guidelines?	To meet air quality guidelines and standards, and prioritise management need	21.1		28	4	19	20	22	35	11	30
Affordable monitoring methods	Are there alternatives to standard methods that can be used to more cost-effectively measure HAPs and other contaminants in the ambient air guidelines (eg formaldehyde) that will also provide reliable results?	To help fill the information gap re concentrations of HAPs found in NZ and to manage guideline contaminants (e.g. arsenic and BaP etc)	23.9		8	3	24	32	22	36	32	34
	What cost-effective real-time methods can be adopted for quantifying natural sources of PM (including marine aerosol and dust)?	Better manage anthropogenic PM emissions	19.3		14	11	9	12	22	23	31	32
	What cost-effective methods should be adopted for quantifying the key constituents of PM (e.g. organic and elemental carbon, sodium, chlorine, potassium, nitrate, sulphate and ammonium)?	Quantify and manage the main constituents of PM10 and PM2.5	19.5		10	19	8	22	26	12	25	34
	Can cost-effective methods be developed for non-NES contaminants (e.g. BaP etc)?	Quantify and manage guideline contaminants (e.g. arsenic and BaP etc)	24.3		25	6	23	32	26	24		34
Measurement (national consistency & QA & representativeness)	What is the cost and benefits of standardised modelling practices (eg arbitration panels, good practice guides, exemplars, certificate of modelling competency etc) to improve effectiveness of model use?	To help ensure emission reduction targets and AEEs based on modelling are credible and defendable.	15.5		3	29	27	5	5	30	11	14
	What are the costs and benefits of establishing a national AQ monitoring programme, including data repository, for PM10 and other contaminants?	To produce high quality and nationally consistent monitoring data most cost-efficiently that can be accessed through one portal and has long term security of storage.	9.3		7	12	21	8	2	3	11	10
	What are the cost and benefits of establishing a - national procedures for monitoring and national air quality monitoring training programme, including and a national facility for servicing and calibrating monitoring instruments and auditing monitoring sites?	To produce high quality and nationally consistent monitoring data most cost-efficiently.	18.6		12	16	22	9	36	33	11	10
	What cost-effective monitoring methods can and should be used for other guideline contaminants (e.g. BaP, formaldehyde, arsenic)?	To quantify and manage guideline contaminants (e.g. arsenic and BaP etc)	24.5		26	6	17	32	26	32	21	36
	Could alternative methods of screening or measurement be used to best locate equipment and/or reduce cost of monitoring PM2.5 and PM10?	To produce high quality and nationally consistent monitoring data most cost-efficiently.	15.6		9	18	16	4	26	13	29	10

Known Management needs												
Domain/Broad research area	**Question**	**Management need**	**Average**		**Auckland**	**Waikato**	**Wellington**	**Canterbury**	**BOP**	**Hawkes Bay**	**Otago**	**Taranaki**
IMPACT of State												
Human health effects (inc. natural sources & air toxics)	Are there health effects from natural sources of PM and how do these contribute to the overall impact?	To understand the impact of natural sources on health in order to prioritise management response.	20.9		30	24	18	30	19	4	11	31
	What health impacts are associated with airborne soil contaminated with agrichemicals?	Prioritising management need and ensuring the issue is addressed	9.1		1	1	7	7	19	11	11	16
	What are the hydrogen sulphide odour threshold levels for communities exposed to hydrogen sulphide as opposed to those who are not?	For the assessment of specific activities (geothermal power developments and also WWTP's, composting operations etc)	7.9		2	5	2	6	14	1	11	22
	What are the potential health effects in communities/populations exposed to current concentrations of air toxics and are the current MfE ambient air guidelines still relevant?	To manage those contaminants likely to have the greatest impact in NZ and set appropriate guidelines/standards	20.6		32	14	15	29	19	18	11	27
Social consequences	Are the most susceptible and exposed populations being adequately protected?	To get the best outcomes from a health perspective by targeting management responses	16.6		33	20	12	14	7	14	11	22
	How much does air quality affect amenity values and influence their decisions (i.e where you live)?	To help understand the wider impacts of air quality on communities	6.5		6	2	1	10	7	2	2	22
RESPONSES to Pressure-State												
influencing human behaviour & understanding barriers to change	How can we influence perceptions and behaviour of householders to improve ambient air quality?	For better buy in from the community and a greater chance of meeting guidelines and standards	27.8		31	21	33	36	34	28	11	28
	What is the relative importance of the various barriers (eg lack of insulation, fuel poverty) to adopting clean heat to improving air quality? And how can these barriers be overcome?	For better buy in from the community and a greater chance of meeting guidelines and standards	22.8		21	8	14	36	34	29	11	29
Multi-pollutant management	What other approaches could be used to reduce emissions from wood burners (large-scale solutions, technology, gross emitters etc) and would these also reduce concentrations from contaminants such as BaP, PM2.5 and arsenic?	To provide a better guarantee of NES compliance and possibly other standards/guidelines	20.6		20	25	32	26	16	31	11	4
	Are the guideline contaminants being addressed (in both terms of regional monitoring and policies) in a nationally consistent and robust manner?	To understand how we might increase and improve the response to risks posed by guideline contaminants.	14.4		22	9	13		3	27	11	16
	How much will our policies on PM10 improve/drive reductions of other contaminants and will this be enough to meet other standards and guidelines?	To understand integrated outcomes for improved responses	21.0		34	13	26		3	34		16
Technological solutions	Can technological advances in emissions control (eg for domestic burners) achieve emissions reductions whilst still allowing domestic burning to continue?	To provide a better guarantee of NES compliance and possibly other standards/guidelines	23.0		5	32	29	24	34	20	36	4
Broader solutions (inter-relationships energy/housing/climate change)	Are measures adopted at the national and regional level the most effective for managing PM10 and associated contaminants (e.g. are there broader infrastructure/energy related solutions that may be more effective)?	To provide a better guarantee of NES compliance	23.6		24	31	20	34	26	15	35	4

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Known Management needs

Domain/Broad research area	Question	Management need	Average		Auckland	Waikato	Wellington	Canterbury	BOP	Hawkes Bay	Otago	Taranaki
RESPONSE effect on 'impact'												
Understanding effectiveness of responses	Are risks to health decreasing in response to lower PM concentrations (i.e., are we seeing the same improvements in health from reductions in wood smoke as we would from motor vehicle dominated PM and are they similar to that reported overseas)?	Ensure strategies target those sources with the greatest impact on the health of the population	17.6		36	22	11	28	14	9	11	10
	Are current evaluation methods (inventories, dispersion modelling, receptor modelling) the most cost effective and providing quality outcomes? Are there alternative methods to emission inventories for source attribution that better link emissions and concentrations ?	To provide more certainty regarding NES and guideline compliance, and to ensure that strategies are fair and not overly restrictive	22.0		13	33	35	17	14	26	28	10
	Are low emission wood burners delivering the reductions predicted relative to older burners in the field?	Determine if management response is effective and to know if further response is required	26.8		27	27	25	27	32	22	30	24
	Do we have the tools to accurately track progress towards AQ goals in a nationally consistent manner? Which are the best?	To allow reactive management based on the success or otherwise of current strategies and to facilitate and apply consistency in tracking progress towards NES compliance	24.0		29	16	34	21	16	17	34	25

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14.3 Prioritisation of Research Questions for Emerging/New Issues

New and Emerging Issues									
Domain and broad research area	Question	Management need	Average	Auckland	Waikato	Canterbury	BOP	Hawkes Bay	Taranaki
Pressure									
Information gaps re air toxics (eg, BaP, PAH) & PM2.5	What PM2.5 monitoring has been done in New Zealand and what does it tell us?	To understand the significance and risk of potential management issue	9	12	9		12	7	5
	What are the similarities/differences with PM2.5 and PM10 concentrations?? How does the ratio change with location, weather patterns and season?	To understand the significance and risk of potential management issue	7.8	8	8		11	9	3
	Are there other contaminants (for which there are no guidelines or standards) that we should be measuring ? And are there cost-effective methods for monitoring?	To understand the significance and risk of health effects, determine need for standards/guidelines	6.6	6	1		6	12	8
State									
Measurement (national consistency & QA & representativeness	What are the feasibilities and costs of establishing and operating a representative national PM2.5 monitoring network?	To provide a clear consistent national understanding of state (and associated uncertainty) and regional variability	4.2	7	4		8	1	1
Impact									
Human health effects (inc. natural sources & air toxics)	What is the current state of knowledge regarding health impacts associated with PM2.5 and it's sources in NZ?	To understand risk to health and need for new guidelines and standards?	7.8	10	7	8	10	5	7
	What does international research tell us about the impact of different contaminant mixes on health? What is the relevance of this to NZ?	To aid small-scale AQ management, protect against cumulative health effects	8.5	4	10	11	7	10	9
	What PM2.5 guideline, standard or policy should there be in NZ?	To improve health outcomes	8.4	11	3		9	8	11
	What non-standard/ guideline contaminants have been highlighted as potential health issues overseas and may also be an issue in NZ?	To understand risk to health and need for new guidelines and standards	6.7	5	2	11	1	11	10
Exposure assessment and management	Should NZ shift focus from concentration exceedance to exposure (ie reducing exposure across the whole population instead of targeting hot spots where there are exceedences) as is happening internationally?	To get the best outcomes from a health perspective by targeting management responses	6.7	1	12	7	2	6	12

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New and Emerging Issues										
Domain and broad research area	**Question**	**Management need**	**Average**		**Auckland**	**Waikato**	**Canterbury**	**BOP**	**Hawkes Bay**	**Taranaki**
RESPONSES to Pressure-State										
Scenario Assessments	How do we manage for a reduction in PM2.5 and how does this differ from existing and proposed regional intervention strategies?	To improve health outcomes	5.6		9	6		5	2	6
Multi-pollutant management	What is relationship of PM10 with other air toxics (multi-pollutant management) and how does this relate to emissions sources?	To understand integrated outcomes for improved responses	4.7		3	5	11	4	3	2
	Should management take into account contaminant mix (ie multi-pollutant) rather than managing on an individual pollutant basis? If so how could this be applied to NZ?	To manage air quality at a smaller community scale (i.e. different areas will have different mix of contaminants - particularly near industry etc)	5.8		2	11	11	3	4	4

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