Engineering lifelines and transport – should New Zealand be doing it better? Part one

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Engineering lifelines and transport – should New Zealand be doing it better? Part one

Phase 1: Situation scan
Phase 2: New Zealand risk exposure

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Part one: Executive summary; Phase 1: Situation scan; Phase 2: New Zealand risk exposure.
Part two: Phases 3 and 4: Gap analysis and solution development.

Keywords: asset management, engineering lifelines, natural hazards, risk

An important note for the reader

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Abbreviations and acronyms

AELG	Auckland Engineering Lifelines Group
ALA	American Lifelines Alliance
AMP	Asset management plan
CDEM	Civil defence and emergency management
CELG	Canterbury Engineering Lifelines Group
GIS	Geographic information system
GNS	Institute of Geological and Nuclear Science
LGA	Local Government Act 2002
LTCCP	Long-term council community plan
LTP	Land transport programme
MCDEM	Ministry of Civil Defence & Emergency Management
MCEER	Multidisciplinary Center for Earthquake Engineering Research
NELC	National Engineering Lifelines Committee
NIWA	National Institute of Water and Atmospheric Research
NLCC	National Lifelines Coordinating Committee
RCA	Road controlling authority
TLA	Territorial local authority
WELG	Wellington Engineering Lifelines Group

Contents

Executive summary

Introduction

This project examined New Zealand engineering lifelines activity, its level of integration in road controlling authority management practices, and its relationship to the resilience of roading networks to natural hazards.

The research was divided into four phases:

- Phase 1: Situation scan
- Phase 2: New Zealand risk exposure
- Phase 3: Gap analysis
- Phase 4: Solution development.

The report has been published in two parts: Part one contains Phase 1 and Phase 2; and Part two contains the merged Phases 3 and 4.

In the report, the term 'engineering lifelines activity' or other references to 'lifelines' refers to a collaborative inter-utility and cross-sector planning process to reduce the pre- and post-emergency impacts of low probability disaster scale events.

This summary provides a full overview of the research project.

Phase 1: Situation scan

This phase involved:

- an international search for best practice
- New Zealand lifelines practice review
- comparisons with international practice/desired practice
- a review of legislative obligations – the Local Government Act 2002 (LGA) and the Civil Defence and Emergency Management Act 2002 (CDEM Act)
- the development of a comparative analysis approach.

International practice

International practice is variable. In many countries with higher levels of risk exposure, there is no evidence at all of a lifelines focus.

The United States is strong on analytical, data-intensive and technology-focused solutions, such as a geographic information system (GIS) which is used for mapping asset inventories. This spills over into lifelines.

Japan is strong in terms of understanding and predicting potential hazard events and in applying design methods to improve engineering resilience. There does not appear to be a strong lifelines culture involving collaboration and relationship between sectors.

The United Kingdom has an understanding of hazard events and risk management. Again, there does not appear to be a significant lifelines culture in evidence, perhaps because the seismic risk is lower.

Australia, which faces fewer natural hazards than New Zealand, the United States and Japan, also does not appear to have a significant lifelines culture. There is a strong focus on 'disaster prevention', and a number of authorities have initiated or undertaken lifelines studies.

In these countries, there is a strengthening view that future work needs to focus on the vulnerability of communities.

New Zealand practice in comparison

The following observations emerged from the Phase 1 research:

- New Zealand's combined approach to assessing multiple hazards and multiple lifelines utilities seems to be unique in the world.
- There is lifelines activity throughout most of the country, although the level varies considerably.
- The focus has tended to be on reduction through mitigation and planning.
- Many groups/projects have a role in supporting CDEM groups in their region.
- There is no overall view of the extent to which the resilience of road networks has been improved, nor whether wider social/economic consequences are considered by road controlling authorities (RCAs).
- There seems to be a general lack of integration of lifelines in roading asset management plans (AMPs) – with this being cited by some as a potential major barrier.
- A need is seen for identifying priority routes for restoring the services of other lifelines utilities.
- The effectiveness of the interface between RCAs in an emergency event needs to be considered.

Legislation

Under the LGA, long-term council community plans (LTCCPs) have a role to play in the lifelines context, particularly in terms of risk and managing community expectations.

The CDEM Act requires all 'lifeline utilities' to:

- function to the fullest possible extent during and after an emergency
- have plans for such functioning (continuity) that can be made available to the Director of the Ministry of Civil Defence & Emergency Management
- participate in CDEM planning at national and regional levels where requested
- provide technical advice on CDEM issues where reasonably required.

This requires a sound understanding of lifelines issues affecting the network.

Comparative analysis approach

A national comparative analysis approach was developed which included the following criteria:

- level of formal lifelines organisation
- hazard identification
- asset vulnerability (failure) assessment by utility
- impact (consequences) assessment
- planning and implementation of mitigation actions
- community awareness
- lifelines relationships
- application of technology (eg geographic information system (GIS)).

Phase 2: New Zealand risk exposure

This phase involved:

- a review of New Zealand's natural hazards
- the development of a broad risk exposure mode
- a comparative analysis of lifelines activity at the group/project level
- the identification of transport infrastructure resilience measures for use in asset management planning.

Natural hazards

The following hazards were considered:

- flooding
- meteorological
- coastal – storm surge and tsunami
- landslide
- seismic
- volcanic.

Risk exposure

A qualitative risk assessment was conducted, following the methodology in the risk management standard AS/NZS 4360 (Standards NZ 2004) and an overall rating or 'risk index' assessed for each region.

The risk exposure results were compared against the relative size of the economy in each region, highlighting the particular significance of Auckland and Wellington with other regions such as Canterbury and Waikato also significant in terms of risk exposure.

This also showed that lifelines activity was focused across areas with a wide range of risk. While the degree of lifelines management was at a high level in areas with greatest risk there were some at-risk areas where there had been limited lifelines activity.

This information could also be used to assist with strategic analysis of risk-based investment across the country.

New Zealand lifelines approaches

Typically, this is centred on regional boundaries, but some areas operate at a sub-regional level. There are usually two levels, a 'project' which is a one-off study, or a 'group' which has an on-going focus. RCAs are typically involved in such activity, but to different degrees. A lifelines coordinator or project manager forms a contact point in each area.

The following are findings from a survey of these lifelines contacts:

- In the regions where lifelines groups have been established with a project either completed or underway, natural hazards have been well identified and the likely impact on the roading network is well understood.
- The impact that a roading network failure would have on other utilities is also well understood.
- In some cases, there has been limited action to mitigate against the impact of a natural disaster.
- There is a perception that very little funding has been specifically targeted at improving the roading network's resilience to natural disasters.
- There is limited communication and/or not a good understanding of what different groups are doing.

Resilience measures

Resilience relates to the ability of a system or network to continue to support the community and meet the community's social, economic and environmental needs, following a major hazard event. The development of a systematic resilience-based framework could provide asset managers with a tool that could be used to better understand resilience, network weaknesses, and assist identify priorities for risk investigation and mitigation.

Parameters that could be used to assess resilience include:

- the **resistance** of the asset itself to a hazard event. How much of the network could be damaged and/or unusable after a hazard event, ie the 'damage assessment ratio'
- the **network layout** and whether there are alternative routes
- the **volume** of traffic in relation to the level of service offered by the road
- the **time** that it would take to restore the road network.

Such parameters could be scored and assembled into a matrix alongside critical assets such as bridges and arterial roads, which could then be used as part of the risk assessment procedure in an AMP.

Phases 3 and 4: Gap analysis and solution development

In Phase 3, a written questionnaire was supplemented with some personal interviews with RCA personnel in order to:

- assess RCA practice in terms of lifelines, natural hazards and risk management
- assess the effectiveness of RCAs and their AMPs in relation to these issues
- identify strengths and weaknesses, the likely barriers and the critical gaps
- consider Land Transport NZ's funding allocation methods in dealing with high-impact natural hazard events
- make recommendations in relation to AMP content and the roles of asset managers in relation to lifelines activity
- make recommendations for improving practice in relation to risk management and for strengthening infrastructure resilience.

RCA practice

The following key conclusions/observations have been drawn from the responses to the questionnaire:

- Natural hazard risks are generally well understood, even where there has been little or no lifelines activity.
- There is a better understanding of the effects of the more frequently occurring floods and storms than the infrequent but more severe seismic and volcanic hazards.
- There is a low level of understanding of the 'social and economic' impacts of hazard events, which suggests that these factors may be under-recognised.
- There is generally a very low level of funding for specific works to mitigate or improve the transport network resilience to natural hazards.
- Transit NZ has a useful screening and prioritisation process for projects that have route security benefits.
- The low level of funding directly allocated to risk mitigation by local authorities reinforces the conclusion that engineering lifelines practices and inter-utility collaboration have not been significant business drivers.
- While risk is becoming more important to asset managers, the application of lifelines principles in integrating a hazard-based risk management process across all lifeline utility sectors in a district is not apparent in most AMPs.
- There is very limited use of technology by local authorities in the areas of asset management and lifelines. Transit NZ has a number of hazard monitoring and information systems.
- Robust measures are not being used for assessing the resilience of roading networks, nor for assessing the economic, social, environmental or cultural impacts of hazard events.
- There is a view that communities are knowledgeable and well prepared for natural hazard events.

Asset management plans, CDEM and technology

There is insufficient information covering risks and natural hazards in AMPs. Very few plans have any information or maps showing lifelines or key emergency routes and only one provided specific details of projects targeting hazard mitigation. Where funding was provided for mitigation work the AMP seldom contained much detail or provided links to other background documents.

The CDEM Act identifies important functions for CDEM groups and lifeline utilities. CDEM, lifelines and asset management functions should be well linked, systematically addressed by RCAs and documented in AMPs, including reference to disaster resilience summaries.

Improvements and detailed recommendations were made in relation to these main points:

- Asset (and activity) management plans should be enhanced to meet best practice guidelines for risk management.
- Lifelines engineering assessments conducted in collaboration with other lifeline utilities should be explicitly referenced in the AMP, so that this information can be shared and accessed by staff and stakeholders.
- A recommended template for risk management and engineering lifelines content in an AMP should be promoted as desired best practice.

Further work should be undertaken in defining ‘resilience’ measures, against which the effectiveness of different investments in strengthening, risk reduction or readiness can be assessed.

Furthermore, the vulnerability of infrastructure assets and the consequential risks to communities should be important determinants in optimising priorities for new assets, replacement, rehabilitation and maintenance works. GIS technology can provide benefits in terms of presenting information to decision-makers, and visualising and analysing the spatially related effects of hazards on infrastructure.

Funding signals

Funding levels for natural hazard mitigation works appear to be very low in relation to total expenditures on the roading network and the historical costs of emergency works. Few local authorities are spending more than nominal amounts on forward mitigation works. While there appear to be a number of reasons for this, it would be helpful if positive funding signals could be provided, especially on key lifelines routes once these have been clearly identified in AMPs with mitigation projects supported regionally.

Monitoring of progress

There are no mandatory monitoring processes in place for CDEM and lifelines projects and actions. While the National Engineering Lifelines Committee (NELC) regularly monitors progress of the various groups and projects around the country, monitoring at the local level is ad hoc, inconsistent and depends on the enthusiasm of local staff.

Table E1 Summary of project conclusions in relation to research objectives

Research objectives	Project findings
Has the engineering lifelines approach increased the resilience of New Zealand's land transport system?	Both the 'discipline' and the work carried out to date have had some positive impacts on the resilience of the land transport system, although it is not possible to assess this quantitatively. It is important that practitioners at the local level become more involved and see lifelines studies through to the implementation phase. A positive aspect is the integration of locally based activity with the NELC, and this must continue – as it provides opportunity for local action within a nationally accepted framework.
How well is the engineering lifelines approach integrated into other natural hazard mitigation approaches, and into AMPs?	Integration of the engineering lifelines approach with hazard identification, management and mitigation is generally effective at the national and lifelines group/project levels. However, practice varies considerably at the AMP level and in most cases there is very little information about how hazards may affect the infrastructure.
Has the local regional approach to lifelines planning provided the best overall result for the country?	The regional approach has allowed individual areas to progress lifelines planning to suit their circumstances, within a generic national framework and with support from other regions. Furthermore, utilities with a national view are able to participate and contribute through the national coordination and information sharing approach of the NELC.
What is international best practice and what gaps are there between this and New Zealand practice?	New Zealand has a particular strength in terms of our multiple hazard planning and collaboration processes, and the willingness of many agencies to participate in lifelines. However, there are barriers to achieving effectiveness and full national integration. Best practice elsewhere sees more extensive use of technology and damage/loss prediction scenarios. However, New Zealand is making progress in these areas, such as through the work of NIWA and GNS. This technology needs to be understood and applied by local practitioners.
What risks is New Zealand land transport infrastructure exposed to (likelihood and consequence)?	There is a diverse range of natural hazard events that have the potential to severely disrupt the land transportation sector and these have been highlighted in the research. The effects vary depending on location, and some regions face quite different risks to others. While seismic, volcanic and tsunami events are rare, their effects on infrastructure and communities will be very significant. It is likely that these effects, and their interdependencies, are not as widely understood by asset managers as the more frequent flooding, landslide and meteorological events which while also significant locally are generally well understood.
What are the barriers to improving New Zealand's performance in this area?	Barriers include workload and short-term demands for investment, a sense that lifelines planning is optional, an overly optimistic approach by asset managers to response capability and 'managing on the day', and funding constraints in terms of strengthening infrastructure. These include competing with other more immediate priorities, difficulty in justifying work, and weak funding signals and incentives.
What available tools and technology could enhance lifelines practice?	Technology can be used in relation to: • spatial data management, mapping and analysis • hazard monitoring

	• modelling and scenario development and prediction. Some are being or have been developed within New Zealand and examples include Transit NZ's screening and prioritisation process and RiskScape (NIWA/GNS).
Future actions and implementation options.	**Recommendations have been made in this report, with a particular focus on:** • **better understanding of 'resilience' and how it can be maximised through better infrastructure management** • **improving AMPs and risk management processes so that lifelines planning is integrated with other investment decision-making processes** • **maintaining and building knowledge around natural hazards and how these will affect infrastructural networks** • **identifying tools that can be used to assess and manage lifelines risks.**

Overall project recommendations

- The results of this research project should be circulated to all RCAs in New Zealand, and AMPs and activity management plans be further developed in relation to risk and the effects of hazards on infrastructure.
- The improvements suggested in this report in relation to AMPs and activity management plans should be considered by the National Asset Management Steering Group (NAMS) for incorporation in future infrastructure management manuals and guidelines.
- Land Transport NZ should develop and publicise examples of assessments for project justification of natural hazard mitigation (reduction) measures in the *Economic evaluation manual. Vol 1* (Land Transport NZ 2007).
- The concepts of resilience measures and monitoring should be further developed by Land Transport NZ in association with key stakeholders such as the NELC and used for national performance reporting purposes.
- An initial measure of resilience, such as the financial exposure of infrastructure to particular hazard events, should be developed by Land Transport NZ, and the use of the RiskScape model explored with the National Institute of Water and Atmospheric Research (NIWA) and the Institute of Geological and Nuclear Science (GNS).
- The NELC should develop a framework to enable lifelines groups to review the effectiveness of completed lifelines projects and studies, in terms of enhanced resilience.

Abstract

This project examined New Zealand engineering lifelines activity, its level of integration in road controlling authority management practices, and its relationship to the resilience of roading networks to natural hazards.

It examined and compared lifelines practice at three levels – international, New Zealand regions and individual road controlling authorities. Relative risk exposures arising from natural hazards and their impacts on regions were assessed at a qualitative level, highlighting the importance of a comprehensive lifelines approach throughout much of the country.

The project found there were many gaps in practice and that it was difficult to align the effectiveness of expenditure with measures of increased resilience.

These gaps present opportunities for improvement, which are described with recommended actions. These include further development of asset management plans, establishing resilience measures, better use of technology for associating hazard events with infrastructural assets, more comprehensive risk management practice and a more proactive approach to funding risk-based investment.

Phase 1: Situation scan

1 Introduction

1.1 Purpose

This project formed part of the Transfund New Zealand (now Land Transport NZ) 2003/2004 Research Programme. Its focus was engineering lifelines and, in particular, efforts made nationally in recent years to improve the resilience of roading networks to natural hazards.

The primary objective of the project was to reduce the impact of natural hazards on land transport infrastructure by investigating:

- whether the engineering lifelines approach had increased the resilience of New Zealand's land transport system
- how well the engineering lifelines approach was integrated into other natural hazard mitigation approaches and into asset management plans (AMPs)
- if the local regional approach to lifelines planning had provided the best overall result for the country
- international best practice and identifying gaps between this and New Zealand practice
- the risks New Zealand land transport infrastructure was exposed to (likelihood and consequence)
- the barriers to improving New Zealand's performance in this area
- available tools and technology that could enhance lifelines practice
- future actions and implementation options.

The research was divided into four phases.

- Phase 1: Situation scan
- Phase 2: New Zealand risk exposure
- Phase 3: Gap analysis
- Phase 4: Solution development.

The report has been published in two parts: Part one contains Phase 1 and Phase 2; and Part two contains the merged Phases 3 and 4.

1.2 Outline of Phase 1

This section of the report:

- identifies international best practice in lifelines planning, mitigation and response for land transport
- describes the current status of lifelines projects and groups throughout New Zealand

- summarises the relevant legislative environment and key obligations on road controlling authorities (RCAs)
- discusses implications for subsequent phases of this research project and develops a simple benchmarking tool.

1.3 Engineering lifelines

Lifelines are those essential 'utility' services which support the life of the community – such as water, wastewater and stormwater, power, gas, and telecommunications and transportation networks.

This research project focused on transportation networks and in particular roading networks. However, there is a high level of dependence by other lifeline utilities on roading networks – for example, water, sewerage, power and telecommunications services all use the road corridor and often also rely on structures such as road bridges. A failure of part of the road network may not only result in the consequential loss of another service, but also make access more difficult to repair and restore the service.

1.4 Hazards

The engineering lifelines process focuses on the effects of hazards from external sources. Traditionally in New Zealand, these are natural hazards such as earthquakes, volcanic eruptions, floods, wind, snow and landslides. However, exposure to technological and man-made hazards is also increasing globally and must be considered in the lifelines context.

1.5 Related research projects

1.5.1 Natural hazard risk management scoping study

This study was undertaken for Transfund NZ by Dr Erica Seville (nee Dalziell) of the School of Engineering, University of Canterbury, and complemented the engineering lifelines project.

The report resulting from the study, 'Developing a hazard risk assessment framework for the New Zealand state highway network' (Seville and Metcalfe 2005) scopes how risk management techniques can be used across the whole of the state highway network to reduce the impact of natural hazards. It builds on an earlier report, 'Risk assessment methods in road network evaluation' (Dalziell et al 1999) which focused on the use of risk assessment methodologies on the Desert Road.

The 2005 report includes a review of international research and experience particularly in relation to transportation networks, assesses the level of information on New Zealand's natural hazards and how this is currently being made available, and communicates with stakeholders, such as road network managers and contractors, to find out their information needs in order to improve their risk management processes. It also looks at how network impacts arising from different road closure events can be modelled, as the network impact of a hazard risk, as opposed to the link-by-link impact, is far more critical and in turn affects social and economic activity levels.

In particular, the areas in which the lifelines project can benefit from this project include:

- assessing the nature and distribution of natural hazard risk to infrastructure in New Zealand
- advancing understanding of natural hazard risks for transportation networks
- using technology such as geographic information systems (GIS) for mapping natural hazard risks to road networks
- using perceptions and observations arising from discussions with stakeholders and key people within the transportation sector
- confirming information needs for the risk assessment process
- considering social and economic impacts.

This will be accomplished by maintaining a working relationship with this project and by drawing on information and findings as it progresses. Similarly, milestone outputs from the lifelines project will be shared with the university research team.

1.5.2 Vulnerability of organisational systems to natural hazards

Further work has been undertaken by Dr Erica Seville for the Foundation for Research, Science and Technology. It focuses on organisational vulnerability and explores how risk management occurs in practice across a range of organisations. In particular it identifies wider business disruption costs[1] arising from impacts on the roading network and develops an associated framework. It samples a range of organisations – including utilities, local authorities, public and financial institutions, supermarkets, exporters and small businesses, and tries to define 'resilient organisations' and identify key features of their crisis plans.

A three-stage process has been adopted and the project:

1. considers supply chain linkages and levels of reliance from a systems perspective
2. studies how organisations with networked systems respond to hazard events and recover from them. Transit NZ has been case studied and the processes used to optimise competing priorities examined – for example, is there a focus on key areas or is response diversified across the network? It looks at how to develop a dynamic system to manage the immediacy of data capture and the need to adapt response and priority
3. examines the legal and contractual frameworks for reconstruction post-event.

1.5.3 Opus research on natural hazard risk management for road networks

Opus International Consultants undertook two research projects for Transfund NZ which focused on the development of a systematic approach for managing risk from natural hazards. These projects are documented in Brabhaharan et al. (2001), Brabhaharan (2002) and Brabhaharan et al. (2006).

[1] Overseas experience shows that business disruption costs typically far exceed the loss of property/damage costs.

This paper identifies a procedure for prioritising risk treatment based on a GIS spatial analysis approach. It involves a systematic assessment of links in a road network, considering various natural hazards, event probabilities and consequences.

It proposes a scoring system based on various factors, and a five-level integrated risk management framework – from national level to projects level.

This appears to be a sound process which has been used in localised case study situations. It uses a wide range of data, is suited to local analyses, but may be too complex to use when applied to a wider network.

Further work should focus on simplifying the approach and using it as an input to risk management in AMPs.

1.5.4 New Zealand Centre for Advanced Engineering (CAENZ)

CAENZ (as CAE 1997) published the report *Risks and realities* on the Christchurch engineering lifelines project, a study which examined the lifelines implications from a range of natural hazards that could occur. CAENZ's objective is to advance social progress and economic growth in New Zealand by broadening national understanding of emerging technologies and facilitating early adoption of advanced technology solutions. Its programme areas include infrastructure system and risk management. CAENZ is expected to take an active interest in the outcomes of this research project.

Figure 1.1 Rock slips are common occurrences in NZ's mountainous terrain.

2 International practice

2.1 Sources of information

International practice has been assessed through research conducted through a website search, a literature search and contact with David Brunsdon of the New Zealand National Lifelines Coordinating Committee. David provided a number of reference sites (included below) and material from the 2003 United States Technical Council on Lifelines Earthquake Engineering (TCLEE) Conference. This conference is an important international event for sharing information on lifelines practice. In addition, contact has been made with transportation specialists in other AECOM offices throughout the United States, United Kingdom and Australia.

Not surprisingly, there is a strong focus on earthquakes and more recently on terrorism impacts.

2.2 Websites visited

2.2.1 United States

There is a range of organisations involved in some way in engineering lifelines and hazard assessment work. The first site shows that the United States is developing a coordinated approach to promoting national lifelines efforts.

www.americanlifelinsesalliance.org
American Lifelines Alliance (ALA).

This is a public-private partnership project formed in 1998 and funded by the Federal Emergency Management Agency, with a goal of reducing risks to lifelines from all natural hazards and more recently man-made hazards such as terrorism attacks. ALA stresses the importance of taking a systems-based approach to assessing expected lifeline performance and of understanding overall system functionality.

ALA draws attention to a lack of uniformity in identifying systems risks and implementing measures to improve earthquake performance in coastal California, with even more sporadic and varied attention elsewhere across the United States.

> *Decisions on where to devote resources for improving lifeline system performance should be prioritised by considering the likelihood of experiencing natural hazard events, the impact of the natural hazards on the system, and the value of improving system performance to the owners of the system and their customers.*

ALA (2003) has developed a *Natural hazards matrix summary* which identifies design standards/guidelines for various lifeline components in relation to natural hazards.

Current projects of interest to transportation lifelines include 'Ice Load Mapping'.

Projects under consideration include 'System Reliability Guidelines for Highways'.

www.eeri.org
Earthquake Engineering Research Institute (EER)

This institute's role is as an authoritative source of earthquake risk reduction information in the United States, and in partnership with other nations, to develop earthquake risk reduction information worldwide.

Its website provides a searchable and comprehensive research base, including the subject of damage assessment.

www.mceer.buffalo.edu
Multidisciplinary Center for Earthquake Engineering Research (MCEER)

The centre's aim is to improve seismic assessment and performance of buildings, highways and other infrastructure, as well as emergency response and recovery systems.

Its programme includes highway research sponsored by the Federal Highways Administration (FHWA), Transport Research Board (TRB) and other agencies. One aspect is a seismic risk assessment methodology that can be applied at local, regional or national level, and it has various projects underway (106, 112 and 094).

This research examines the impact of earthquakes on the highway system as an integrated network, rather than a collection of individual components. The aim is to improve the usability of highways after an earthquake, by improving the performance of all interconnected components. This involves improving understanding of the seismic hazards and developing analysis methods, screening procedures and additional tools, retrofit technologies, design criteria and other approaches to reduce seismic vulnerability.

A system has been developed to determine direct bridge damage losses and costs and predict traffic flow impacts. Further work (Project 094) in determining indirect costs and impacts and the effects of damage to other highway components is underway.

MCEER also has a loss estimation technology focus (eg Seismic Risk Analysis software – REDARS, fragility curves for highway structures).

It undertakes significant bridge-related work, eg improved retrofit technologies, foundation and geotechnical studies. Given that bridges are typically the most vulnerable link in a highways network, this is not surprising. (Often, the approaches of a bridge will be allowed to fail under extreme flooding in order to dissipate flood flows and protect the bridge.) MCEER also undertakes demonstration projects to examine the potential of advanced technologies, such as at various bridge sites in Utah.

www.asce.org
American Society of Civil Engineers (ASCE)

The Technical Council on Lifelines Earthquake Engineering (TCLEE) referred to above is a technical committee of ASCE, and it runs an international conference every four years which is attended by New Zealand representatives. Topics of relevance to this research project from the 2003 conference are described below.

ASCE also has a Transportation Lifelines Committee, which focuses on the component and system performance perspectives of highways, railroads and rapid transit structures, as well as mitigation measures and procedures.

ASCE undertakes a regular assessment of the country's infrastructure. The 2003 report card shows a fall to a D+ rating for roads from 2001.

www.fhwa.dot.gov
Federal Highway Administration, United States Department of Transportation (FHWA)

The FHWA's strategic plan for 2003 included a focus on national security and the vulnerability of the transportation system, but there was no reference to natural hazards. Performance objectives for FY 2003 included:

- Identify critical highway infrastructure, evaluate its risk and vulnerability, and develop measures to reduce vulnerability.
- Ensure preparedness for response to, and recovery from, attacks on highway infrastructure.

www.aashto.org
American Association of State Highway and Transportation Officials (AASHTO)

No results were found on this site from a search on 'lifelines'.

www.dot.ca.gov
Caltrans, California Department of Transportation

Major emphasis is on seismic protection, particularly for bridges. No results were found on this site from a search on 'lifelines'.

www.colorado.edu/hazards/resources/centers.html
The Natural Hazards Centre website provides a comprehensive listing of other locations which study hazards and disasters.

2.2.2 United Kingdom

A United Kingdom website search on the key words 'engineering lifelines' did not produce any useful information relating to lifelines projects in the United Kingdom. Because the

United Kingdom does not have the significant seismic risks of New Zealand, Japan and the United States, there is not the same focus on lifelines.

A search on 'natural hazards' produced several sites and references, although none that appeared to have a lifelines focus. The following site provided a useful catalogue of internet resources for different hazards, such as earthquakes, volcanoes and tsunami – **www.bubl.ac.uk**.

2.2.3 Japan

Like New Zealand and the United States, Japan has a strong focus on the impacts of earthquakes. Japan has experienced significant events (such as the Kobe earthquake in 1995), which have impacted on transportation networks, in particular tunnels, bridges and elevated highway structures. These events have provided an incentive to improve the resilience of networks through retrofitting and new design, but the extent to which the lifelines philosophy of sharing information and collaborative planning across lifelines sectors is promoted in Japan does not seem to be a particular strength.

As indicated below, there is a wide body of information which appears to be focused around research organisations.

www.jinjapan.org/navi/index.html
This site provides information on web links to institutions and agencies within Japan. A search on 'science and technology' brought up many sites, including those noted below.

www.eri.u-tokyo.ac.jp
Earthquake Research Institute, University of Tokyo (ERI)

An extensive information resource for earthquakes. ERI has a Division of Disaster Mitigation Science, although further study of this site was hampered by the fact that it is written in Japanese.

www.jsce-int.org
Japanese Society of Civil Engineers (JSCE)

This site did not lead to any useful information.

2.2.4 Australia

No specific websites describing lifelines activity in Australia have been identified.

www.ipwea.org.au
Institute of Public Works Engineers Australia (IPWEA)

No reference was found to engineering lifelines projects on this website.

A small number of local authorities undertook early work in lifelines (eg Tasmania, Hervey Bay); however, this has not been continued and there is very little work at present. Emergency Management Australia has also carried out work on the structure of lifelines planning.

2.2.5 Other sites

www.geohaz.org/radius/

This website is the home page for the RADIUS project (Risk Assessment Tools for Diagnosis of Urban Areas against Seismic Disasters). The objectives of this programme were to:

- develop earthquake damage scenarios and action plans in nine case-study cities selected worldwide
- develop practical tools for seismic risk management, which could be applied to any earthquake-prone city in the world
- conduct a comparative study to understand urban seismic risk around the world
- promote information exchange for seismic risk mitigation at city level.

www.piarc.org

World Road Association (PIARC)

A search of this site on keywords such as ‘lifelines’, ‘seismic’ and ‘hazards’ did not reveal any significant information.

www.imesa.org.za

Institute of Municipal Engineers, South Africa.

This is a small site and contains no relevant information.

2.3 Specific conferences/papers

2.3.1 TCLEE Conference

Selected papers from the 2003 TCLEE Conference were reported to the National Engineering Lifelines Forum in Wellington by David Brunsdon and Noel Evans who attended the conference.

Key themes of their observations were:

- The TCLEE Conference was strongly research oriented.
- Emphasis on network/system approaches and linkages to economic analysis had increased since the previous (1999) conference.
- GIS was proving to be a significant technological catalyst for a more systems-based approach although methodologies appeared to be very data input and maintenance intensive for the New Zealand situation.
- Performance (recovery) of system components should be assessed in terms of its impact on the overall system. (This was particularly evident in a paper ‘Performance based engineering – the next generation of lifeline earthquake engineering’.)

- More attention needed to be given to post-event status and management, including modelling/forecasting the actual condition of utility assets, rather than generalised family-based 'fragility curves'.
- There was a need to take into account the social context of technology in order to realise intended engineering outcomes.
- Earthquake engineering risk analysis had provided a useful basis for aspects of terrorism risk analysis methodologies.
- Liquefaction prediction needed further refinement.

The conference papers were presented under several lifelines categories, with 25 of the 114 papers covering aspects of highways and rail (network) and bridges.

Transportation papers included:

- 'Current developments and future for seismic risk highway systems' – Stuart Werner.
  This paper describes a methodology for either a deterministic or probabilistic vulnerability analysis, and an associated software package. Use of this package involves significant data input including hazard data.
- 'A GIS-based emergency response system for transportation systems" – Nesrin Basoz/ Anne Kiremidjian
  This paper describes a GIS-based routing application for emergency traffic, with real-time capability in scenario or real event conditions. It requires maintenance of current bridge and road condition information.

Transportation-related risk topics discussed at a pre-conference workshop included:

- 'Component vulnerability modelling issues for analysis of seismic risks to transportation lifelines systems' – Stuart Werner.
  Components need to be assessed for how long they will be out of service due to a given damage state – this involves the development of 'fragility curves' derived from asset functionality, location and design inputs.
- 'The regional economic cost of a tsunami on transportation networks around Los Angeles' – James Moore.
  This considers the economic impacts of disrupting export flows to and from Southern California, suggesting that total losses increase by a factor of 5.

It will be evident from the above coverage of the conference that a significant amount of technical research is being undertaken, particularly technical work focusing on the behaviour of bridges. On the other hand, there still appears to be a significant amount of work needed in relating social and economic community outcomes to lifelines planning and mitigation processes.

2.3.2 Australian Disaster Conference 1999

This conference marked the end of the International Decade for National Disaster Reduction 1990–2000, organised by Emergency Management Australia. It was attended by John Lamb, Christchurch Engineering Lifelines Project Manager. Key themes recorded by John included:

- the need to focus on community vulnerability and resilience, community involvement, and a proactive risk management approach
- the potential to use GIS to assess the impact of the cost of a particular service in various communities
- addressing the problem of loss of 'institutional knowledge' through staff turnover – an issue that could be dealt with through AMPs
- broadening the scope of lifelines to include health authorities
- the need for specific studies of ground condition at critical locations, particularly where liquefaction is possible.
- the development of a framework for assessing vulnerability that includes multiple levels of social life and multiple perspectives on vulnerability and resilience
- understanding multi-hazard risk in urban communities.

2.3.3 'Seismic zonation for lifelines and utilities'

This paper (O'Rourke and Jeon 2001) was sourced through the internet and was the subject of a lifelines presentation by Professor Tom O'Rourke in New Zealand in 2003.

It focuses on the uses of seismic zonation for hazard delineation, physical loss estimation, assessment of economic and social consequences, and planning for emergency response and recovery. GIS databases were used to relate damage (for buried water pipes) to various seismic parameters. This involved a close analysis of repair data, in relation to soil type, pipe depth, street type, topography etc. Contours of 'equal repair rates/km' were produced and related to factors such as soft sands/clays, steep slopes and swamp. This information was linked to ground movement, or 'strain' measurements.

Using aerial photography, pre and post the earthquake event, researchers were able to develop a relationship between repair rates and 'ground strain'. This enabled the development of damage ratios and predictions of damage replacement costs. The process has application to other assets, including building and structures.

Furthermore, by being able to predict the intensity of failures in different ground environments, based on estimated ground strains, restoration and recovery times can be assessed.

Trip matrices on transportation networks can be predicted based on the extent of disruption, both from services failures and structural failures, thus leading to the estimation of social and economic consequences.

2.3.4 Blueprints for Change – The World Congress on Disaster Reduction, August 2002 (ASCE)

This paper was also sourced through the internet. It provides a framework and contains guidance for organisations to work together to improve their ability to identify indicators of physical, social, enterprise and environmental vulnerabilities throughout the world and implement realistic solutions to improve them.

2.3.5 'Retrofit priority of transport network links under an earthquake'

This paper by Sohn et al. (2003) analyses economic impacts, considering final demand loss and transport cost increase. As an aid to comprehensive benefit-cost assessment, it shows that individual links in the network have a different level of economic significance. Links with greater physical disruption are not necessarily the same as those exhibiting the greater economic damage.

2.4 Personal communications

2.4.1 David Brunsdon, National Lifelines Co-ordinating Committee

The most focused lifelines efforts appear to be in New Zealand and the United States. In the latter, there is a strong emphasis on the use of technology (in particular, advanced network analysis using tools such as GIS), while New Zealand has tended to take a more practical and cross-sectoral approach. Lifelines work in the United States (as in all other countries) is organisationally based, whereas the New Zealand approach is based on regional/multi-agency collaboration.

Also, in the United States a lot of work in the transportation sector is targeted at bridges. There is, therefore, likely to be worthwhile design and retrofitting technology for bridges and highway structures that could be applied in New Zealand.

Further information and contacts can be found in the TCLEE Conference papers.

2.5 International practice conclusions

This research project has set out to identify international best practice for engineering lifelines. It is apparent from the investigation to date that lifelines is very much an evolving practice and that it is largely absent in many developed countries.

While hazards such as earthquakes, floods and tsunami have been a feature of life throughout history and in modern times, it is equally true that responses have focused on targeted and specific rather than collaborative actions. For example, bridges may be strengthened based on the amount of traffic they carry rather than the importance of the other lifeline services they may carry. Earthquake engineering for buildings has focused on better design to prevent or control structural failures, but perhaps with little attention to the damage impacts to services associated with the buildings. For example, the disruption resulting from damage to gas pipelines and connections can be just as (or more) catastrophic as the effect on the structure, as occurred with the fires triggered after the Kobe earthquake.

New Zealand's approach to lifelines is fundamentally based on inter-agency understanding and collaboration – by 'overlaying' the services of each agency against the hazard event and understanding the interdependencies, the true magnitude of disruption to the community can be determined. In contrast, a highways agency concerned only about the failure of its own assets, such as bridges, would have little knowledge or awareness of the effects of consequential failure of other utilities' critical infrastructure passing over the bridge (such as a major telecommunications cable or a large water-main serving a community). New Zealand regards this shared communication and collaboration approach as the 'lifelines culture'.

International practice is variable. In many countries, exposed to higher levels of risk exposure, there is no evidence at all of a lifelines focus (eg the 2003 Iran earthquake). In some developed countries, the emphasis on a network/systems approach is increasing, and this appears to be most evident in the United States. However, this focus is almost exclusively on understanding the impacts of hazards on a single network, rather than on a system of interdependent networks.

The United States is strong on analytical, data intensive and technology focused solutions. There is a lot of emphasis (through legislation) on using GIS for mapping asset inventories, and it is to be expected that this will spill over into lifelines. The United States is starting to develop a lifelines culture, through the ALA. It aims to increase resilience by promoting good practice, raising awareness and undertaking specific projects.

Japan appears to be focused on in-depth understanding of potential hazard events, their prediction, and design methods to improve engineering resilience. There does not appear to be a strong lifelines culture involving collaboration and relationship between sectors.

The United Kingdom places an emphasis on understanding hazard events and managing risks. Again, there does not appear to be a significant lifelines culture in evidence, perhaps because the seismic risk is lower.

Australia, which faces fewer national hazards than New Zealand, the United States and Japan, also does not appear to have a significant lifelines culture. Nonetheless, there is a strong focus on disaster prevention, and a number of authorities have initiated or undertaken lifelines studies.

In these countries, there is very much an emphasis on addressing the risks posed by natural hazard events, and an increasing view that future work needs to focus on the vulnerability of communities. This supports current thinking in terms of risk management, and there is no doubt that the development and implementation of a comprehensive risk management programme, which is integrated with planning and programming processes in the organisation, has significant community benefits. This is an ideal role for AMPs, although it is acknowledged that New Zealand is a leader in this field, with other countries only really beginning to develop them. This point is one of the key issues to be addressed in this research project – is engineering lifelines properly integrated into roading AMPs in New Zealand and how effective are they in increasing transport system resilience? Is the regional collaboration approach working at this level?

Another key international theme is the growing potential for GIS to be used, not only for data storage and management but also for lifelines network planning and analysis. Lifelines are spatial in nature and many are now recorded in GIS databases. This also provides an opportunity to capture the knowledge of individual staff members. This aspect should also be canvassed in the research.

The intent to develop a benchmarking tool to compare international practice with New Zealand practice does not appear practical at this time, as the comparison above indicates that New Zealand practice is ahead of other countries in terms of the application of a lifelines culture. New Zealand can, however, learn from the more technically focused work, such as on bridges, and apply it on a case-by-case basis. Also, a comparative analysis of lifelines culture and practice across New Zealand as applied to the roading system can also be undertaken.

3 Current New Zealand practice

3.1 National Lifelines Co-ordinating Committee

The National Lifelines Co-ordinating Committee (NLCC) was formed in 2000 following a period of several years of liaison and new projects assistance provided through the Earthquake Commission. David Brunsdon is the Secretary of the NLCC, and carries out much of its day-to-day workload. Furthermore, all of the lifelines groups and projects look to him to represent their interests on the NLCC.

A number of stakeholders are represented on and fund the NLCC:

- Ministry of Civil Defence & Emergency Management (MCDEM)
- Earthquake Commission (EQC)
- Telecom New Zealand
- Transpower
- Transit New Zealand
- Natural Gas Corporation
- Institute of Geological and Nuclear Sciences.

The NLCC's roles include:

- encouraging establishment of new lifelines projects
- facilitating information exchange and assisting with methodologies
- communication between national utilities and lifelines projects and groups
- linkage between MCDEM and lifelines activities
- liaison with groups in developing best practice guidelines
- promoting research and disseminating information
- organising the annual National Lifelines Forum.

The NLCC estimates that, in addition to its annual budget of $30,000, a further $0.5 million is invested annually in lifelines work, with 'time in kind' leveraging this by two or three times.

3.2 Lifelines groups and lifelines projects

The sequence of development of lifelines activity in an area has usually begun with the establishment of a project, with project members representing lifeline utilities (covering transportation, water supply, wastewater, power and telecommunications), hazard experts and emergency services.

A lifelines project involves the identification and quantification of hazards and their likely impact on identified vulnerable infrastructural assets. A risk assessment using the AS/NZS 4360 framework should be undertaken. This also includes an 'interdependency' analysis, as the failure of one asset may impact on another (eg the collapse of a bridge will sever any services that run across it). Mitigation measures are proposed and actioned by the lifelines utility. These may include modification or treatment of an asset, changes to operating or maintenance practices, or changes to design standards. Benefits of undertaking a project not only include these measures, but also the information sharing process between utilities and the working relationships that result from this.

The next phase of development, once the initial project has been completed, is the formation of a lifelines group. This phase ensures an ongoing focus on lifelines activities, providing support and encouragement to lifelines utilities in undertaking mitigation work, continuing their involvement and developing new lifelines initiatives. It also provides a mechanism for reporting back on progress and maintaining cross-sectoral awareness and relationships.

The following sections summarise the nature of the activity within each lifelines area in New Zealand. These areas are shown in Figure 3.1 below, which is a snapshot of the level of activity when the survey of lifeline coordinators was undertaken (refer S 10). It can be seen that lifelines groups exist in the major centres, and with most areas of the country at least covered by a project. There were gaps at that time, such as Central Otago, Southland and Marlborough in the South Island, and Whakatane, Opotiki and Kapiti in the North Island, where little if any specific lifelines activity has occurred.

3.2.1 Northland

The Northland Lifelines Group was convened in 2004, and in 2006 developed a programme of activities for the group.

3.2.2 Auckland

The Auckland Engineering Lifelines Group (AELG) was established in 2000 and has completed a number of specific projects with others planned or in hand. Examples include the ‘Priority Emergency Routes – Auckland Region’ and ‘Priority Sites for Recovery’.

The group is active and has an operative website for wider communication and information sharing purposes.

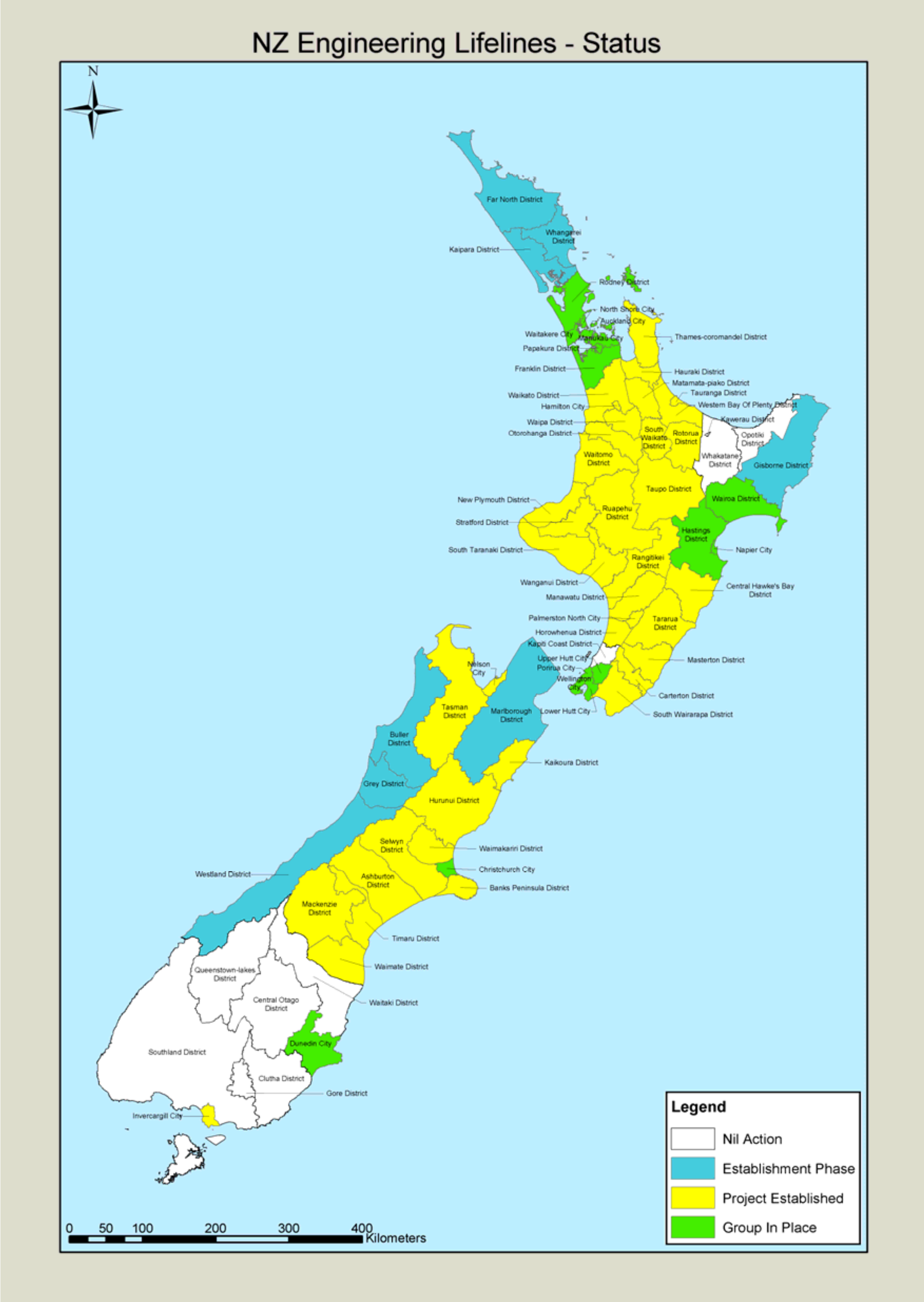


Figure 3.1 Lifelines activity areas as at 2004.

3.2.3 Waikato

A project was initiated in 2000, which undertook vulnerability, risk assessment and mitigation identification work. The present focus is on developing the lifelines group and contributing to the work of the CDEM group in the region. Other lifelines groups are starting to develop similar roles and relationships.

The group's 2007 business plan includes 'supporting asset managers in the production and maintenance of their Management Plans, especially in terms of risk management'.

3.2.4 Bay of Plenty

Hazard reports have been completed for seismic, lightning, volcanic ash and flooding. Tauranga's roading network has been reviewed and a key bridge identified for strengthening. Further work is planned in assessing the effects of flooding on bridges.

A Lifelines Advisory Group is now in place and is following Waikato's approach.

3.2.5 Gisborne

Some work was initiated several years ago with a statistically based approach to analysing risk; however, progress in identifying and undertaking actions at the utility level is uncertain. The area has formed an advisory group to support the CDEM group.

3.2.6 Rotorua

Hazards have been identified and quantified, and the effects on council lifelines only assessed. Specific forward investigations and mitigation works are planned.

3.2.7 Hawkes Bay

The lifelines project report was published in November 2001. Hazards were identified and mitigation actions proposed by lifeline agencies, a number of which have been implemented. The current focus is on the lifelines group's contribution to the new CDEM structure and new projects.

3.2.8 Taranaki

A lifelines advisory group was formed to support the Taranaki CDEM group. It undertook hazard assessment, with future work planned on inter-dependencies and vulnerable 'choke-points'.

3.2.9 Manawatu–Wanganui

A lifelines project has been undertaken, this includes GIS mapping of hazards. A lifelines advisory group has been formed, and has a programme.

3.2.10 Wairarapa

A lifelines report has been published and further work has been carried out on earthquake hazard assessments, and also on liquefaction and other identified hazard effects, both seismic and scour, on vulnerable bridges. An engineering lifelines association has been formed and has completed priority routes and sites projects.

3.2.11 Wellington

Early lifelines work in New Zealand was first undertaken in Wellington. The first lifelines report was published some 15 years ago, and since then a number of activities have been conducted every year. Major mitigation works such as the Thorndon overbridge have been undertaken as a result. Other completed projects include lifelines emergency communications (with AELG), understanding and developing the use of GIS on an inter-agency basis, and a regional Emergency Roading Strategy. New projects include 'hot spots' and reconnection protocols for electricity and gas, demonstrating a wide range of activity.

3.2.12 Nelson Tasman

This was established in the 2002/03 year and hazards research has been undertaken. The report and associated hazard maps were provided to lifelines utilities, followed by a process of assessing vulnerabilities and remedies.

3.2.13 West Coast

An engineering lifelines group has now been established and has undertaken a comprehensive 'bottom-up' assessment based on community needs. Seismic and liquefaction hazards appear to be of most concern in this region

3.2.14 Canterbury

Lifelines work began in the early 1990s, following on from the Wellington project. The project report *Risks and realities* was published in 1997, the main area of focus being Christchurch City and the Port of Lyttelton. Mitigation actions on the road network focused on bridge strengthening/renewal of the local roading network to better resist seismic hazard and liquefaction effects. The project also defined a network of emergency recovery routes.

This project was the first in New Zealand to use a multi-hazard approach. There are now ongoing updates of hazard assessments and efforts have been made to investigate the use of GIS.

The group's main focus at present is further regional engineering lifelines work covering Canterbury. This began by using aerial photographs and distance reference points for visually assessing the effects of hazards on the state highway network. Other work includes priority routes and sites and interdependencies, covering all territorial local authorities (TLAs) in Canterbury, with a desire to see the findings reflected in AMPs and LTCCPs.

3.2.15 Dunedin and Otago

A lifelines project for Dunedin has been completed, and the group has undertaken annual reviews and some projects.

A wider Otago engineering lifelines group has very recently been formed.

3.2.16 Invercargill and Southland

A lifelines project for Invercargill has been published. Mitigation actions are documented and a number have proceeded (eg Transit NZ/Invercargill City Council seismic audit of bridges). A lifelines group has been formed and this has now been complemented by the formation of the Southland Lifelines Group.

3.3 Transit New Zealand – state highway network

Transit NZ is a member of the NLCC as noted above. Transit regional staff have been involved in a number of lifelines projects around the country and a number of actions have been implemented. Specific studies, such as seismic bridge screening, have been undertaken. Various hazards are considered in risk mitigation planning, including earthquake, tsunami, lahar and landslide.

Transit NZ's risk management processes are described in the state highway AMP.

3.4 Observations on New Zealand practice

The following observations have emerged from the findings:

- There is lifelines activity throughout most of the country, although the level of this varies considerably.
- The focus of New Zealand's work has been, and continues to be, on reduction through mitigation works and planning. In terms of the other three 'R's, some effort has been directed to readiness with little collaborative attention being given to response and recovery – although at an individual organisation level the four 'R's receive greater attention.
- Perhaps the key difference with overseas work is New Zealand's combined approach to multi-hazards and multiple organizations. This seems to be unique in the world, certainly at a national level.
- Many groups/projects are looking to their future role in supporting CDEM groups in each region.
- While information is provided through projects and groups to the NLCC, there is in many cases no clear picture of how road networks have been 'treated', nor whether the wider social/economic consequences have been considered by RCAs.
- A 'cutting to the chase' process is needed in lifelines so that early progress can be made in identifying key asset vulnerabilities and potential mitigation treatments.
- There seems to be a general lack of integration of lifelines in roading AMPs – with this being cited by some as a potential major barrier. This aspect certainly needs to be explored with RCAs, and the degree of attention given to the four 'R's reviewed. Should more be done?
- For example, a need is seen for AMPs to define those routes that will be needed as priority routes in restoring the services of other lifelines utilities. These routes can then be given priority in terms of improvement/protection. This also requires clear understanding of the needs of the utilities.

- Under the LGA, TLAs must prepare LTCCPs to describe their activities and to outline the role of infrastructure assets in meeting community outcomes. They will draw input from more detailed AMPs and activity management plans. LTCCPs, therefore, have a role to play in the lifelines context, establishing and communicating levels of risk exposure, how risk will be managed and also to manage risk expectations in the community.
- In reviewing the role of LTCCPs and AMPs, there is a need to look at how extensively the AS/NZS 4360 Risk Management Standard is being applied.
- The effectiveness of the interface between local authorities and Transit NZ in an emergency may also need to be explored.

Further information was obtained from each of these areas. A questionnaire was used in the second phase of this project to determine what actions had been undertaken on roading networks in each area, and the perception of the lifelines group/project coordinator on the ongoing lifelines programme, activities and level of commitment of RCAs. Further questions, such as how does each group/project ensure that the actions proposed by RCAs are implemented in a timely way, were also addressed. This was followed up, as proposed in the brief, by a specific survey of RCAs.

4 National environment

4.1 Legislation

4.1.1 Local Government Act 2002

The LGA came into effect in December 2002, introducing a number of significant changes for local authorities.

One change was the increased emphasis on long-term planning, integration with asset management, and the requirement to identify community outcomes and prepare an LTCCP. The content of an LTCCP with respect to assets is detailed in Schedule 10 of the LGA, with clear requirements to identify assets, the negative effects of assets, impacts of changes to levels of service or demand, future capacity needs, how maintenance and renewals will be undertaken, and the associated costs.

While the LGA is not specific about the area of risk management, the need can be inferred. Furthermore, the Controller and Auditor-General has stated that this is a key area which local authorities need to improve on, especially in their AMPs. It can be expected that future audits of AMPs and LTCCPs will focus critically on risk management.

4.1.2 Civil Defence Emergency Management (CDEM) Act 2002

This Act came into effect on 1 December 2002, replacing the Civil Defence Act 1983.

The CDEM Act improves and promotes:

- the reduction of risks through partnerships with communities
- the reduction of community disruption from avoidable hazards and risks
- the reduction of fiscal risks from the costs of disruption
- more effective and efficient emergency readiness, response and recovery through the integrated activities of responsible agencies and relevant disciplines
- a culture, processes and structures that encourage and enable people and communities to undertake risk management and build operational capabilities for response and recover from emergencies.

The purpose of the CDEM Act is to:

- improve and promote the sustainable management of hazards to contribute to well-being, the safety of the public and the protection of property
- encourage and enable communities to achieve acceptable levels of risk by applying risk management
- provide for planning and preparation for emergencies and response and recovery in the event of an emergency
- require local authorities to coordinate CDEM through regional groups

- integrate local and national CDEM planning and activity
- encourage the coordination of emergency management across emergency sectors.

Civil defence emergency management groups (CDEM groups) are a core component of the CDEM Act. A CDEM group is a consortium of the local authorities in a region working in partnership with emergency services, amongst other things, to:

- identify and understand hazards and risks
- prepare CDEM group plans and manage hazards and risks in accordance with the 4 'R's (reduction, readiness, response and recovery).

The CDEM Act provides for groups to form across all regions.

Note that these groups are not the same as lifelines groups – the latter being a voluntary grouping of organisations formed to further cross-sectoral lifelines activity in an area. They can also play a significant role in contributing information and advice to CDEM groups to assist the latter in meeting their legislative requirements.

The CDEM Act defines 'lifeline utilities' in Schedule 1. These include all entities that provide a road network (including state highways).

Section 60 of the CDEM Act requires all lifeline utilities to:

- function to the fullest possible extent during and after an emergency
- have plans for such functioning (continuity) that can be made available to the Director of the Ministry of Civil Defence & Emergency Management
- participate in CDEM planning at national and regional levels where requested
- provide technical advice on CDEM issues where reasonably required.

4.2 Lifelines and CDEM planning

The Ministry of Civil Defence & Emergency Management (2003) jointly with the NLCC has produced a best practice guide (BPG1/03) for lifelines and CDEM planning, aimed specifically at individual lifeline utilities and lifelines groups.

It applies particularly to those utilities that have an essential role in managing regional or national scale risks.

Lifelines utilities are expected to participate in cooperative planning relationships:

- between utilities, and within and across sectors
- at the regional (CDEM group) level
- at the national level.

Lifelines utilities are regarded as essential members of CDEM groups and their agreement with other members on targets and actions is needed. Lifelines groups may be used by CDEM groups to coordinate reduction and readiness planning inputs. Utility activities in these phases include:

Reduction/mitigation

- hazard analysis
- network mapping
- vulnerability studies
- prioritised mitigation lists
- risk reduction and cost-benefit analysis.

Readiness

- priority emergency routes
- emergency communications
- contact arrangements
- command centre operation
- public relations and crisis management.

5 Comparative approach proposed

The project proposal included the development of a simple benchmarking tool based on the findings of overseas practice and for use in comparisons with New Zealand practice.

However, as noted earlier, the investigations indicated that New Zealand was well advanced in lifelines practice and culture, certainly in its methodology and approach, and an international benchmarking process would add little value to what had already been found.

There are a number of potential future directions above and it is proposed that these be incorporated in a national comparative process. This can include aspects such as level of organisation, key lifelines steps, community involvement and cross-sector relationships. This approach was used initially to categorise the level of lifelines activity throughout the country – in relation to roading networks by obtaining the perspective of the lifelines groups/projects – and then to explore the RCA level.

The criteria for the comparative review included:

Level of formal lifelines organisation

- none at all
- initiating – small core, with gaps, and no formal agreed plan
- project – with cross-sectoral input and a nominated project manager
- group – with cross-sectoral membership and a nominated project manager

Hazard identification

- hazards not yet formally identified
- hazards known to exist, but not comprehensively assessed for the purpose of lifelines
- hazards identified and described and their likelihood/probability of occurring assessed by appropriate experts in their field

Asset vulnerability (failure) assessment by utility

- no knowledge of the effect of natural hazards on roading network
- effects broadly understood but not analysed systematically
- effects understood and systematically analysed

Impact (consequences) assessment

- no knowledge of the wider consequences of asset roading network failure due to hazard
- consequences of failure on other utility lifelines understood
- consequences of failure on other utility lifelines and wider social and economic impacts understood

Planning and implementation of mitigation actions

- no action taken

- some actions planned for – partial coverage
- benefits and costs assessed and actions programmed – full coverage

Community awareness

- community has little or no knowledge of the impacts of hazard events on the roading network
- community has some awareness
- community has high level of awareness

Lifelines relationships

- roading entity has no formal or a weak relationship with other utilities and emergency services agencies, in relation to lifelines planning
- some evidence of a relationship, but this is occasional and more reactive than proactive
- strong, documented relationship, with regular communication, information sharing and joint meetings/workshops/exercises

Application of technology (eg GIS)

- technology is not used for lifelines purposes
- there is a desire to use technology (eg GIS) to improve lifelines knowledge and application, but little progress is being made
- technology is being used with some success

6 Conclusions on the future development of this project

Phase 1 of the project has provided an overview of national and international lifelines practice, and identified a number of relevant research organisations and initiatives.

The lifelines process is developing further overseas and in particular is giving more emphasis to social and economic consequences and the concepts of community vulnerability and resilience.

Technology and in particular computer applications such as GIS, are being increasingly developed and used (especially in the United States). This is useful not only for analysis purposes, but also simply for recording knowledge.

A comparative analysis approach was developed to allow the project to better quantify how effectively RCAs have contributed to the lifelines effort. This perspective was first obtained from each lifelines group/project area (rather than the RCA) and used in finalising the survey questionnaire given to a sample of RCAs from around the country.

The next phase of the project was to consider the relative distribution of New Zealand's risk exposure level and develop measures to assess whether the level of roading network resilience across the country was appropriate.

Phase 2: New Zealand risk exposure

7 Introduction

7.1 Outline of Phase 2

This section of the report:

- summarises the types of natural hazards that occur in New Zealand and the natural hazard research that is undertaken by regional councils and other agencies
- develops a broad risk exposure model and compares relative risk exposure levels in different areas of the country to natural hazard events with the level of lifelines planning activity, as well as with other key indicators such as the size of the local economy
- reports on the results of a comparative analysis of lifelines activity at the group/project level
- identifies possible transport infrastructure resilience measures for use in asset management planning and discusses whether they are appropriate.

7.2 Engineering lifelines

Lifelines are essential utility services which support the life of the community – such as water, wastewater, stormwater, power, gas, telecommunications and transportation networks.

The project focused on transportation networks and, in particular, roading networks. However, there is a high level of dependence by other lifeline utilities on roading networks, for example, water, sewerage, power and telecommunications services all use the road corridor and often also rely on structures such as road bridges. A failure of part of the road network may not only result in the consequential loss of another service, but also make access more difficult for repairing and restoring the service.

7.3 Hazards

The engineering lifelines process focuses on the effects of hazards from external sources. New Zealand natural hazards include earthquakes, volcanic eruptions, floods, wind, snow, landslides and tsunamis. However, exposure to technological and man-made hazards is also increasing globally and must be considered in the lifelines context.

7.4 Outcome of Phase1: Situation scan

Phase 1 provided an overview of national and international lifelines practice and identified a number of relevant research organisations and initiatives.

The investigations indicated that New Zealand has performed well in lifelines practice and culture, certainly in its methodology and approach, and an international benchmarking process would add little value to what has already been found.

The findings indicated that a number of areas of New Zealand lifelines practice should be explored and a comparative study of lifelines organisations and road controlling authorities (RCAs) was proposed for Phases 2 and 3 of the study.

8 Natural hazards

8.1 Research

The initial step in this phase was to identify natural hazard research commissioned by regional councils and other agencies.

There has been considerable research of natural hazards in New Zealand over a period of many years. The majority of this research has been carried out by the universities, the National Institute of Water and Atmospheric Research (NIWA), the Institute of Geological and Nuclear Science (GNS) and their predecessors. A range of smaller locally based companies have also undertaken natural hazards research. Some of this research has been commissioned by regional councils to assist them in preparing for disaster management, and some by lifelines organisations.

Between them NIWA and GNS have established the Natural Hazards Centre with the aim of providing New Zealanders with a single point of contact for the latest research, resources and scientific expertise in the area of natural hazards. This centre provides information and links to a wide range of ongoing research as well as information on recent hazard events.

A major part of a recent research project (Seville and Metcalfe 2005) was the assessment of information available on the country's natural hazards and the probability of occurrence of the different hazards. This assessment included both existing and ongoing research and provided appropriate linkages to assist with keeping the information current for future studies.

The research report, 'Developing a hazard risk assessment framework for the New Zealand state highway network' (Seville and Metcalfe 2005) provides detailed information about the cause of each hazard type, the key research that has been carried out, and the consequences for, and vulnerability of, the state highway network to each hazard. The information for each hazard type is presented in a summarised form, as shown in Figure 8.1 which provides an example of information on the flooding hazard. This report should be referred to for more in-depth information on hazard events.

The remainder of this section provides a very brief description of the different natural hazards and a pictorial New Zealand-wide view of regional differences in the likelihood of occurrence of each major hazard.

8.2 Flooding hazard

Flooding is the most common and, for many parts of New Zealand, the most significant natural hazard. This is because many of the areas most susceptible to flooding are also attractive places to live in and earn an income. In terms of transport a large number of roads and bridges are vulnerable to inundation or erosion while a river is in flood.

All of New Zealand's river valleys and plains are susceptible to flooding to some degree. The report 'Flood frequency in New Zealand' by McKerchar and Pearson (1989) provides details and methods for estimating flood flows for given return periods. The report also provides maps with the necessary information for calculating flood flows for almost all catchments in New Zealand.

In many areas the flood risk has been modified by the construction of stopbanks or river control systems. These can significantly reduce the amount of flooding and damage from flood flows that are less than the design flow but can also lead to more extensive flooding and damage if they are breached by a greater than design event. The North Island floods affecting the Manawatu–Wanganui region in 2004 are a good example of this.

The potential for more intensive storms as a result of global warming and the ability of the atmosphere to hold more moisture as it warms up, can only increase the frequency and magnitude of floods and hence the significance of this hazard.

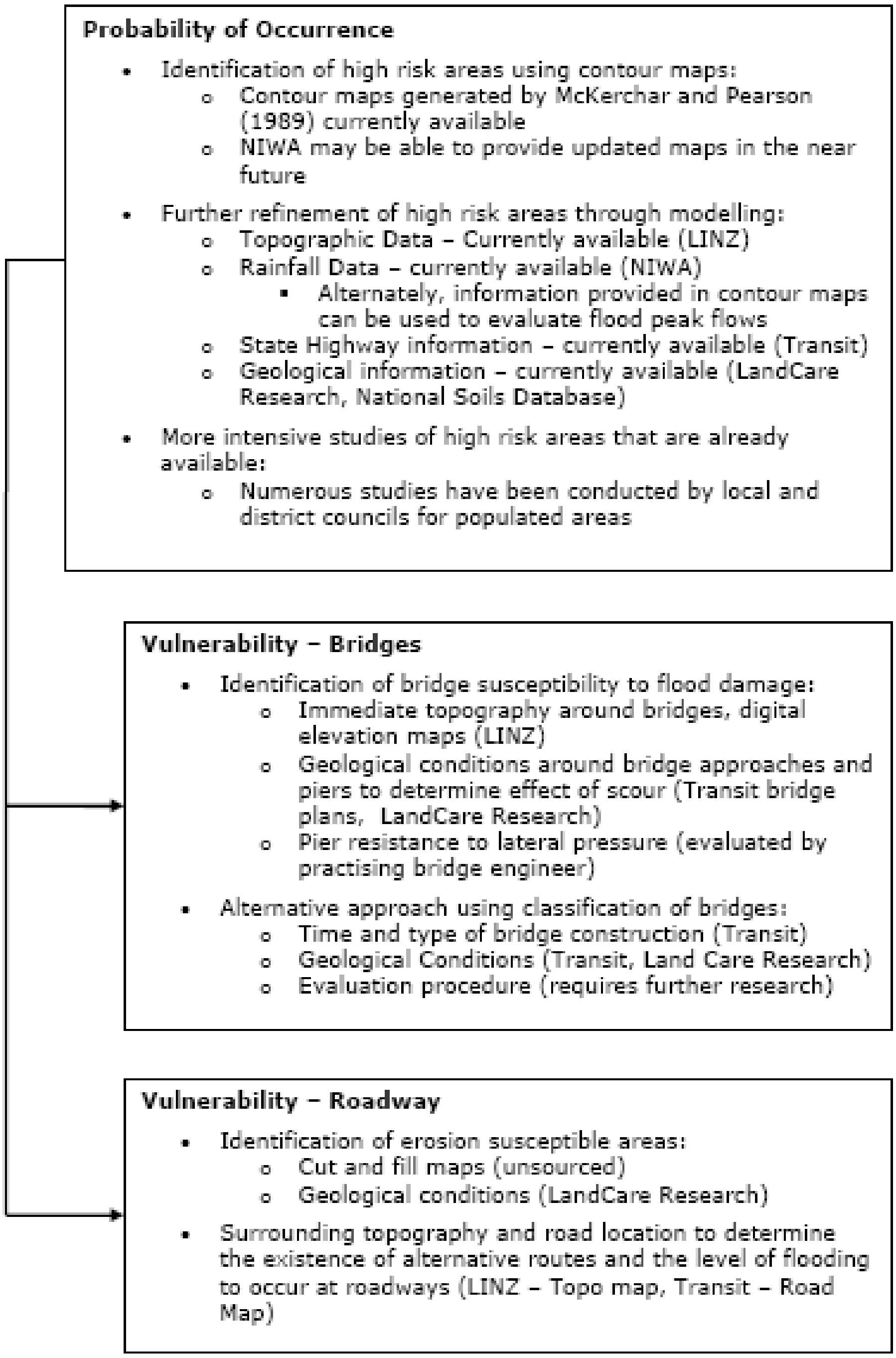


Figure 8.1 Summary of information availability for flooding hazard taken from Seville and Metcalfe (2005).

Figure 8.2 Effects of flood hazard can include significant disruption of road networks.

8.3 Meteorological hazards

Meteorological hazards include severe storms, weather bombs, heavy or prolonged rainfall, snow, snow avalanches, temperature extremes, fog, ice, high winds and climate change.

Snow and ice are frequent occurrences on New Zealand roads, particularly in the South Island and central North Island. Snow avalanches are restricted to the South Island mountain passes and in particular the Milford Road.

Other meteorological hazards have limited impact on road transport but may create difficult or dangerous driving conditions when occurring.

Weather events such as the October 2000 weather bomb depression shown in Figure 8.3 result in severe southerly storms that can affect the east coast of both islands. This example affected Christchurch and Banks Peninsula.

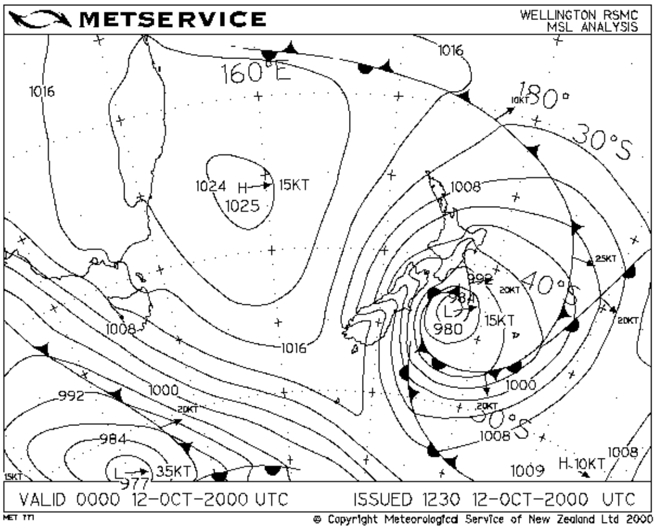


Figure 8.3 October 2000 weather bomb depression.

Storms such as these can result in the closure of State Highway 1 on the Kaikoura Coast and flood roads and properties along Wellington's south coast. Wind can affect traffic and in 2002 a truck was blown over by wind on the Hundalee Hills south of Kaikoura.

8.4 Coastal hazard – storm surge and tsunami

8.4.1 Storm surge

There are significant erosion and seawater flooding issues around many parts of the coast although there are a limited number of roads at risk. Coastal storms and cyclonic events (eg Bola) can result in significant coastal inundation and/or damage. NIWA has indicated that there will be an increase in risk from coastal hazards over the next 20 to 30 years due to climate variability arising from the Intercedal Pacific Oscillation. This risk is seen as highest on the east coast.

Figure 8.4 from the United States illustrates the significant elevation in water level that can occur there due to storm surge. This is simply water that is pushed toward the shore by the force of the winds swirling around the storm. Low atmospheric pressure also results in sea level increase and the advancing surge can combine with normal tides to create storm tides. In addition, wind-driven waves are superimposed on the storm tide. This rise in water level can cause severe flooding in coastal areas. The currents created by the tide combine with the action of the waves to severely erode beaches and coastal highways.

Figure 8.4 Effects of storm surge.

8.4.2 Tsunami

There is also the hazard posed by inundation from a tsunami or tidal wave generated by an offshore earthquake or volcanic eruption. The risk is considered highest on the northern and eastern coasts of both islands. Tsunamis are normally associated with undersea earthquakes close to South America but they can be generated by sub-sea events close to New Zealand. NIWA has shown that an underwater slip off the Kaikoura coast could generate a sudden up to 10 m high wave along this coastline.

Large tsunamis can potentially cause very significant damage but they occur very infrequently. Smaller tsunamis which cause little or no damage are more frequent.

Following on from the 2004 Indonesian tsunami, GNS produced a report *Review of tsunami hazard and risk in New Zealand* (Berryman 2005). This also considered a distant earthquake source to be the most likely to generate tsunami. The report provides probability based estimates of tsunami wave heights and return periods at various points around the New Zealand coastline, which is useful information for lifelines managers. For example, 50%ile estimates for Timaru range from 1.3 m (50 years), 4.6 m (500 years) to 8.2 m (2500 years).

Considerable overland run-up can be expected, with significant damage during a tsunami wave's advance and retreat phases.

8.5 Landslide hazard

Landslide hazards are present throughout New Zealand. They are not strictly a hazard in their own right as they are typically the result of either rainstorm-induced or earthquake-generated slope failures, or a combination of both. Certain soil and/or rock types in different parts of the country are more vulnerable than others and this can be mapped. GNS has prepared a landslide hazard model for the North Island based on soil/rock types.

Minor landslides onto or beneath roads are a frequent occurrence throughout New Zealand during storm events. During the 2004 Wanganui–Manawatu region heavy rainfall flood events a very large number of slips occurred resulting in major disruption to the roading network. Remedial work was still being undertaken many months later. However, major landslides that damage large sections of roads occur infrequently.

8.6 Seismic hazards

All of New Zealand is susceptible to seismic hazards but the anticipated intensity varies across the country. This is represented on the GNS seismic hazard map, showing peak accelerations for any given time period or more simply by the zoning maps in the current building code.

Seismic activity can also cause liquefaction of some soils with consequent damage to roads and structures.

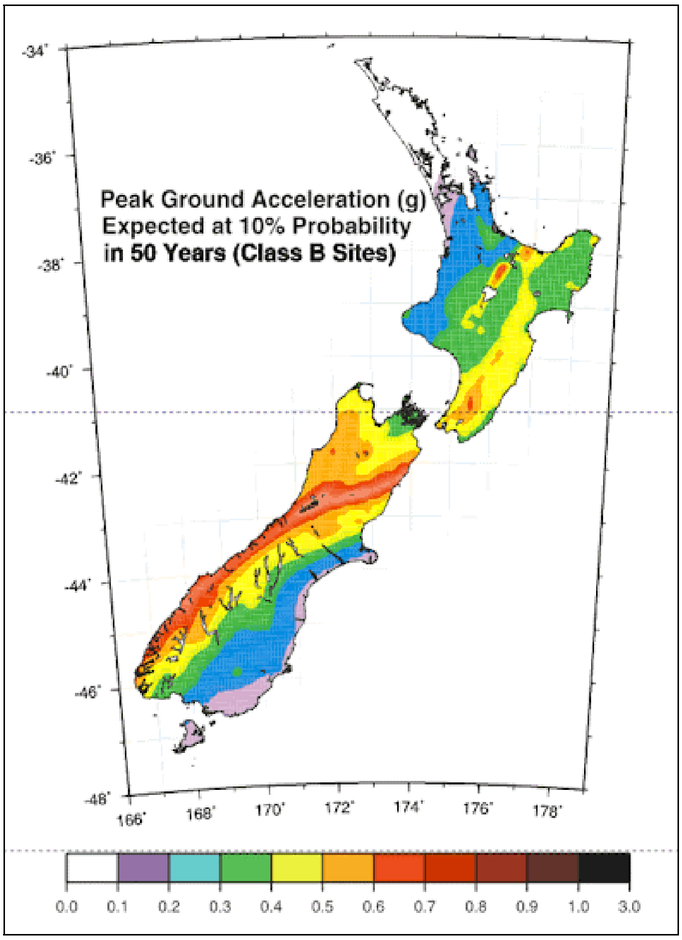


Figure 8.5 The output of the model employed in the GNS report shows the peak ground acceleration that has a 10% likelihood of occurring in the next 50 years.

8.7 Volcanic hazard

The potential for volcanic activity is confined to the North Island and there are three different hazards: ashfall, magma flows and lahar or volcanic flooding. The first, ashfall, presents a hazard to a significant part of the North Island, while the others would be more localised to the area of volcanic activity. The Ministry of Agriculture and Forestry (MAF) has produced information on New Zealand volcanoes and their likely return period and magnitude of eruption. Hazard maps are currently being developed by GNS.

Volcanic eruptions occur very infrequently but potentially have a very high impact when they do occur. Recent examples of a high-impact eruption would be the Tarawera eruption or an Auckland event similar to the formation of Rangitoto Island several hundred years ago.

Even small levels of ashfall can create dangerous driving conditions and road closure may be necessary if the size of the eruption increases. The map below shows possible ashfall depths in the Waikato region from a Ruapehu or White Island eruption. Similar maps are available for other regions where different wind directions will influence the distribution.

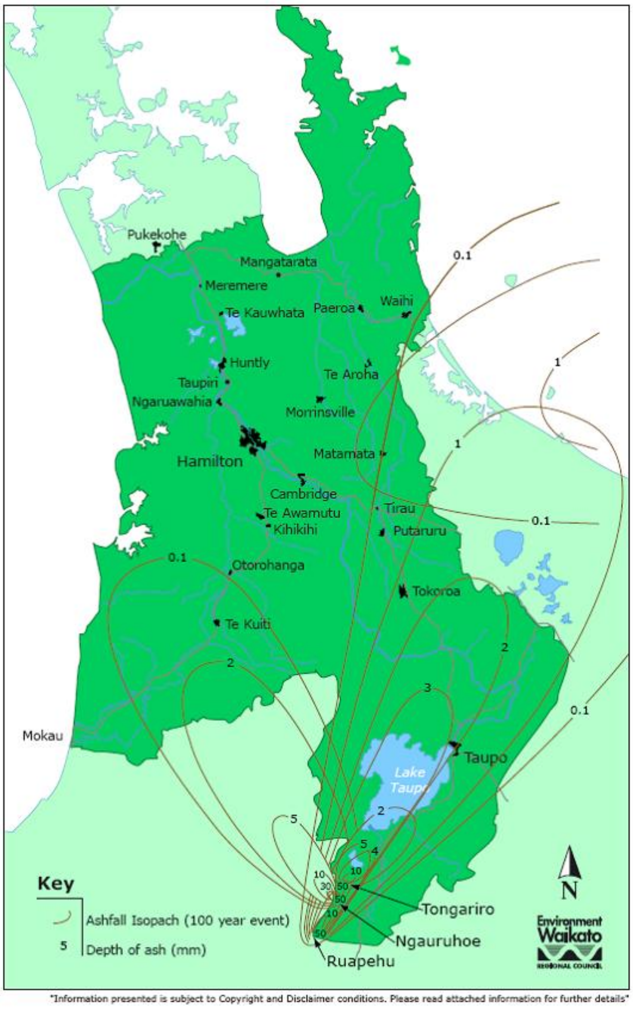


Figure 8.6 Map showing ash distribution in the Waikato Region from Ruapehu or White Island eruption (Source Environment Waikato).

8.8 Geographical distribution of natural hazards

The following diagrams provide an initial overview of the relative extent to which natural hazards could affect different parts of the country. Flooding and landslide hazards are not shown here as these events typically occur with similar intensity or effect throughout the country.

The seismic hazard distribution is derived from the New Zealand specification NZS 4203 General structural design and design loadings for buildings (Standards NZ 1992).

The volcanic, tsunami and snow and ice hazard distributions are derived from qualitative historical information and known areas of higher likelihood of an event occurring. For example, it is known that the east coast of New Zealand is more likely to be exposed to a tsunami (Pacific Ocean) than the west coast. Thus, these diagrams should be regarded as indicative only. High is the most likely.

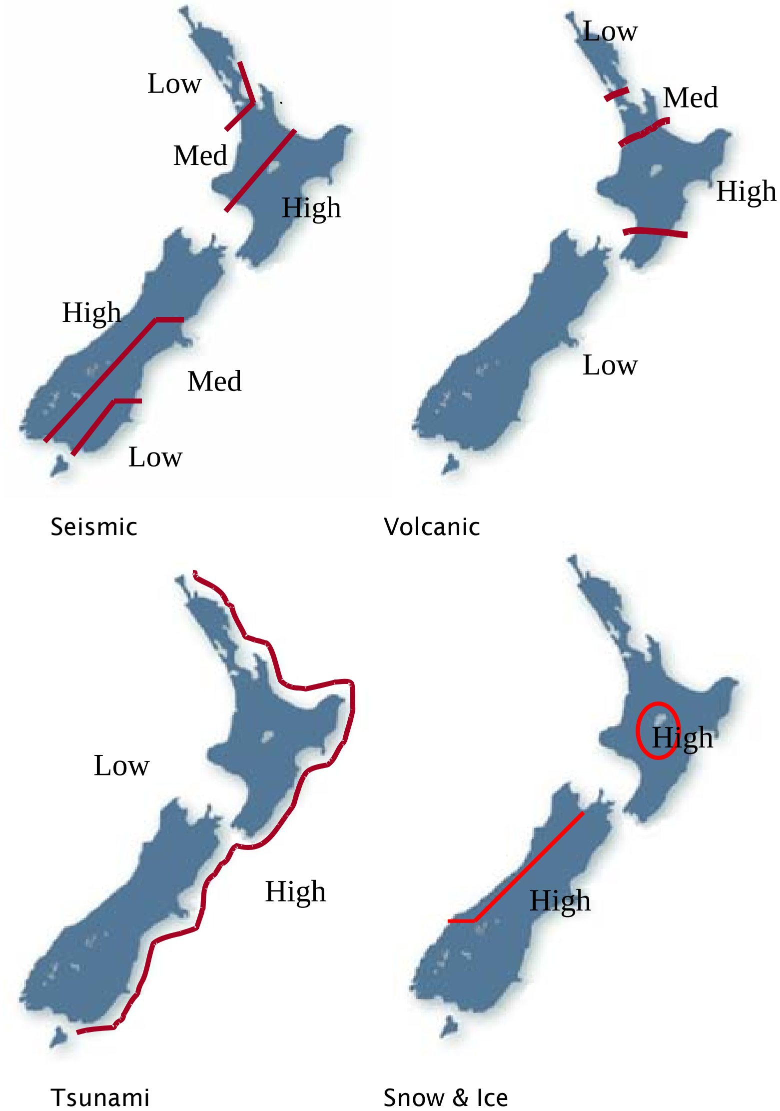


Figure 8.7 Maps showing where a significant natural hazard event is relatively more likely to occur in NZ.

8.9 Hazard research conducted within regions

Given the different levels of lifelines group/project work throughout the country, it could also be expected that there would be significant differences in expenditure on natural hazard research and the associated regional/local impacts. Such research is very important as it provides RCAs with a robust starting point for assessing lifelines risks on their networks.

The following table summarises the types of hazard research that have been undertaken in recent years by regional councils. Many of their websites contain good public information and descriptions of hazard types, and have links to other regional councils and to other hazard information sites. Information on the actual cost of hazard research undertaken (which would provide an indication of the depth and robustness of the research) has not been obtained in this study.

Table 8.1 Hazard research reported publicly by regional councils in 2004/05.

Regional council	Website address	Comments
Northland	www.nrc.govt.nz	Links to NIWA, meteorological service, GNS etc
Auckland	www.arc.govt.nz	Link to lifelines project work and research into volcanic hazards
Waikato	www.ew.govt.nz	References to all hazards including tsunami and volcanic ashfall
Bay of Plenty	www.boprc.govt.nz	Good hazard description particularly for seismic and volcanic. Good maps
Gisborne	www.gdc.govt.nz	No information found in search
Hawkes Bay	www.hbrc.govt.nz	Link to lifelines project (Facing the Risks) Also recent work on coastal hazards
Taranaki	www.trc.govt.nz	Information on flooding and volcanic activity
Manawatu-Wanganui	www.horizons.govt.nz	Refers to lifelines project
Wellington	www.wrc.govt.nz	Link to lifelines projects for Wellington Engineering Lifelines Group (WELG) and Wairarapa lifelines project
West Coast	www.wcrc.govt.nz	Very limited information
Canterbury	www.ec.govt.nz	Reference to lifelines work and link to *Risk and realities*.
Otago	www.orc.govt.nz	No information found in search
Southland	www.src.govt.nz	No information found in search
Tasman	www.tdc.govt.nz	No information found in search
Nelson	www.ncc.govt.nz	No information found in search
Marlborough	www.marlborough.govt.nz	No information found in search

8.10 Natural hazard impacts on the transport network

The typical impacts that natural hazards have on the transport system are summarised in the table below.

Table 8.2 Hazard events, which could typically be expected to occur with a 100-year period.

Hazard type	Description of hazard and effects	Impact on road transport
Flooding	Severe flooding in a river system Stopbank failures in some areas Localised flooding in low lying areas	Road closures or washouts, with detours essential but of limited duration, up to several days Bridge failures from debris or approach washouts, requiring reinstatement or replacement – disruption possible over many weeks
Meteorological	Severe windstorm Intense rainfall Severe snowfall and ice	Dangerous driving conditions Road closures possible typically up to several days Limited or localised asset damage
Coastal	High waves with wind and storm surge Significant storm erosion of beaches, and cliff/shorelines may retreat as a result Small tsunamis which cause little if any damage or disruption	Storm damage to coastal roads with some closures and/or need for detours lasting several days
Landslide	Significant rainstorm generated landslides Localised earthquake generated slope failures or ground subsidence	Road closures of several days depending on site safety Road failures from subsidence or material falling on road
Seismic	Small earthquake within a region or large earthquake outside of region	Total or partial closure of some routes for some days to weeks due to bridge failure or rupture of road surface Localised asset damage
Volcanic	Small quantities of ashfall which may be widely distributed	Visibility reduced and ashfall on roads, with possible intermittent road closures

Table 8.3 Infrequent hazard events, which would be unlikely to occur within a 100-year period, but typically with significant consequences.

Hazard type	Description	Impact on road transport
Flooding	Very severe flooding in one or several river catchment systems and associated plains Major stopbank failure(s) or overtopping adjacent to urban areas	Severe disruption, typically in a single and/or neighbouring region(s) Many bridges and approaches damaged with major washouts Roads submerged for more than one week Areas isolated and/or detours may be required for many weeks to months because of damage
Meteorological	Extreme storm event involving wind and/or rain Very heavy snowfall	Unsafe to drive Road closures and disruption during the event of a week or more Limited asset damage but more significant if is associated with landslides
Coastal	Very high waves with wind and storm surge, possibly major cyclone Long-term coastal changes may result from the event Large scale tsunami which inundates low lying land over an extensive part of the coastline	Road inundation, washouts and bridge damage, with disruption effects lasting several weeks to months
Landslide	Large earthquake generated avalanches and landslides in hill country Earthquake after heavy rainfall	Closure of alpine and hill country routes for weeks to months Local but significant asset damage which can take many months to restore
Seismic	Large magnitude earthquake within a region	Total closure of some routes for weeks to months due to damage to structures Very significant asset damage
Volcanic	Large quantities of ashfall and debris	Potential closure of large parts of the road network within a region. Very disruptive if activity is prolonged

Also of importance are the interdependencies between roads and other lifeline utilities. These are not specifically assessed in this table; however, the cascade effects of the failure of a part of the road network could include loss of access by other lifeline utilities and emergency services, and direct failures of other service assets such as pipes and cables which are located on roadways or road structures that fail in the event. There may also be cascade effects resulting from the failure of other lifeline utilities on the road network, such as major water mains bursting and washing out roadways or bridge approaches.

The hazard events, impacts on roading networks, and interdependencies with other lifeline utilities all need to be considered by RCAs in planning responses to natural hazard events..

9 Relative probability and risk exposure of hazard events

9.1 Risk management approach

The universally accepted risk management process is outlined in AS/NZS 4360 (Standards NZ 2004) and is illustrated in the figure below:

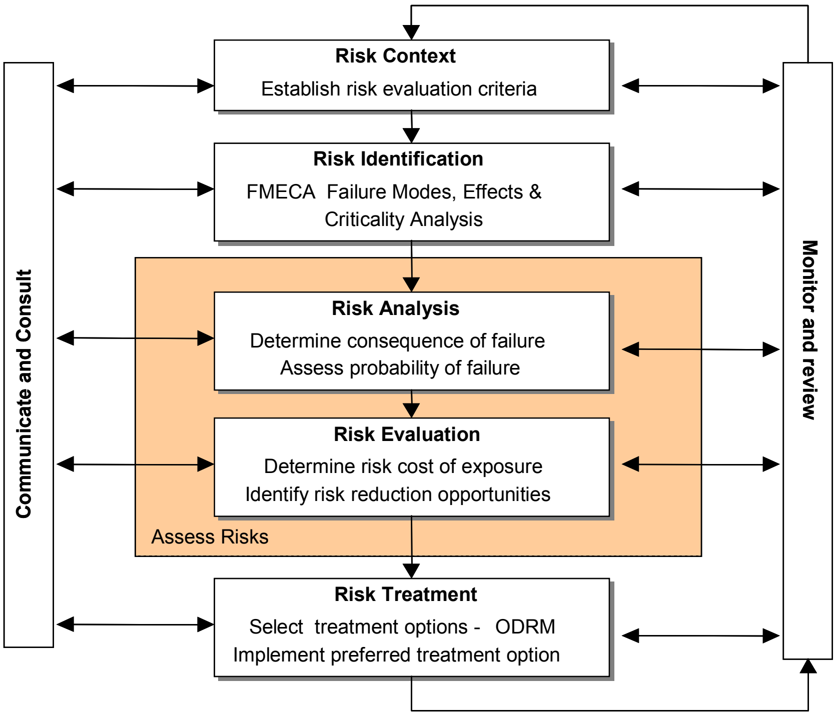


Figure 9.1 Risk management process.

The overall objectives of a formal risk management approach in an organisation should be to:

- outline the process by which the organisation will manage risk associated with its assets, so that all risks can be identified and evaluated in a consistent manner
- identify operational and organisational risks at a broad level
- allocate responsibility for managing risks to specific staff to improve accountability
- prioritise the risks to identify the highest risks that should be addressed in the short to medium term.

Risk management terms and definitions are as follows:

- **Consequence**: the outcome or impact resulting from an event
- **Event**: occurrence of a particular set of circumstances
- **Frequency**: a measure of the number of occurrences per unit of time
- **Hazard**: a source of potential harm or a situation with a potential to cause loss

- **Engineering lifelines**: key infrastructure networks which communities depend on for everyday life, including transportation, water supply, wastewater, power and telecommunications
- **Likelihood**: a general description of probability or frequency, expressed qualitatively or quantitatively
- **Probability**: a measure of the chance of an occurrence expressed as a number between 0 and 1
- **Risk**: the chance of something happening that will have an impact on objectives. It may be specified in terms of an event or circumstances and the consequences that may flow from it. Risk is measured in terms of a combination of the consequences of an event and their likelihood.

The assessment that follows is subjective but based on this risk management approach. It is very broad and at a high level, as this report is based on comparative assessment rather than detailed analysis. The purpose is not to present a robust risk analysis, but rather to highlight indicative levels of risk exposure that different parts of the country face. These areas typically align with the level at which lifelines activity is being conducted.

The hazards are those that have been described in the previous section. In order to simplify the assessment for comparative purposes, only more significant events are considered here. Lesser scale events, while they may occur more frequently, have less impact and are more readily managed on a day-to-day basis. This does not mean they are any less important from a management and response planning point of view.

Relative ratings have been assumed for event consequence and likelihood for each hazard type, and for each locality. These ratings are then combined to form a relative risk exposure rating, which can then be used in comparative analysis.

Note also that some events will only occur in certain parts of a region, such as snow and ice affecting the Desert Road in the central North Island plateau – this also affects parts of both the Manawatu–Wanganui and Waikato regions.

9.2 Consequences

The relative consequences of the hazard events are assessed in relation to the areas where lifelines activity has been undertaken or is underway, as well as those regions where there has been little if any effort to date. The assessment is subjective and uses the relative distribution of hazard information presented earlier.

A hazard event that could conceivably occur in each region/area, and cause significant damage and/or disruption, is considered in terms of the following rating scale.

These terms are similar to those used in asset management planning.

Table 9.1 Categorising disruption consequences.

I/N - nil or insignificant	**Unlikely to lose service. Moderate if any inconvenience.**
Minor	Temporary loss of an engineering lifelines service such as roads and bridges, which could last for several days. Some disruption, although this tends to be localised. Major routes if blocked can be detoured as a response measure.
Major	Short term loss of more than one engineering lifelines service (eg roads and power), considerable inconvenience and possible loss of life. Disruption could last several weeks, and road detours are not usually available within the area. Significant impact on local economy.
Critical	Medium term loss of multiple engineering lifelines services and moderate loss of life. Disruption could last for months. Major social and economic impact on the local community.
Catastrophic	Incapacitating loss of most engineering lifelines services requiring major external support for a considerable period. Disruption over a period of months to years. Potentially major loss of life and devastating impact on local economy.

Table 9.2 Relative consequence ratings.

RELATIVE CONSEQUENCE RATINGS

Area			**Hazard Event**			
	Seismic	**Coastal**	**Volcanic**	**Landslide**	**Flooding**	**Snow / Ice**
Northland	Major	Major	Minor	Minor	Major	I/N
Auckland Region	Critical	Major	Critical	Minor	Major	I/N
Waikato	Critical	Minor	Critical	Minor	Major	Minor
Taranaki	Major	Minor	Critical	Minor	Major	I/N
Bay of Plenty	Critical	Major	Critical	Minor	Major	I/N
Rotorua District	Critical	I/N	Critical	Minor	Major	Minor
Gisborne District	Critical	Major	Major	Minor	Major	I/N
Hawkes Bay	Critical	Major	Major	Minor	Major	Minor
Manawatu/Wanganui	Critical	Minor	Major	Minor	Major	Major
Wairarapa	Critical	Minor	Minor	Minor	Major	Minor
Wellington Region	Catastrophic	Minor	Minor	Minor	Major	Minor
Nelson/Tasman	Critical	Minor	I/N	Minor	Major	Minor
Marlborough	Critical	Major	I/N	Minor	Major	Minor
West Coast	Catastrophic	Minor	I/N	Minor	Major	Minor
Christchurch City	Critical	Major	I/N	Minor	Major	Major
North Canterbury	Critical	Major	I/N	Minor	Major	Major
South Canterbury	Major	Major	I/N	Minor	Major	Major
Dunedin City	Major	Major	I/N	Minor	Major	Major
Otago	Major	Minor	I/N	Minor	Major	Major
Southland	Major	Minor	I/N	Minor	Major	Major
Invercargill City	Major	Minor	I/N	Minor	Major	Major

9.3 Likelihood

The relative likelihood of a hazard occurring is taken further than the indicative maps in the previous section, and is ranked in terms of a broad likelihood scale: frequent, probable, remote and extremely remote. These definitions are similar to those used in a number of engineering lifelines studies and in asset management planning.

Frequent	An event which could be expected to occur several times in a 50-year period.
Probable	An event which could be expected to occur at least once in a 50-year period.
Remote	An event which could be expected to occur at least once in a 250-year period.
Extremely remote	An event which could be expected to occur at least once in a 1000-year period, if at all.

The events being considered in this study are 'significant' hazards, which are likely to cause loss of life and/or damage and require declaration of a civil defence emergency. None of the events considered here fall into the 'frequent' level.

Table 9.3 Relative likelihood ratings.

RELATIVE LIKELIHOOD RATINGS

Area	Hazard Event					
	Seismic	Coastal	Volcanic	Landslide	Flooding	Snow / Ice
Northland	Ext Remote	Remote	Ext Remote	Probable	Probable	Ext Remote
Auckland Region	Remote	Remote	Remote	Probable	Remote	Ext Remote
Waikato	Remote	Remote	Remote	Probable	Probable	Remote
Taranaki	Remote	Remote	Remote	Probable	Probable	Remote
Bay of Plenty	Remote	Remote	Remote	Probable	Probable	Remote
Rotorua District	Remote	Ext Remote	Remote	Probable	Probable	Probable
Gisborne District	Remote	Remote	Remote	Probable	Probable	Remote
Hawkes Bay	Remote	Remote	Remote	Probable	Probable	Probable
Manawatu/Wanganui	Remote	Remote	Remote	Probable	Probable	Probable
Wairarapa	Remote	Remote	Ext Remote	Probable	Probable	Remote
Wellington Region	Remote	Remote	Ext Remote	Probable	Probable	Remote
Nelson/Tasman	Remote	Remote	Ext Remote	Probable	Probable	Remote
Marlborough	Remote	Remote	Ext Remote	Probable	Probable	Probable
West Coast	Remote	Remote	Ext Remote	Probable	Probable	Remote
Christchurch City	Remote	Remote	Ext Remote	Probable	Remote	Probable
North Canterbury	Remote	Remote	Ext Remote	Probable	Probable	Probable
South Canterbury	Remote	Remote	Ext Remote	Probable	Probable	Probable
Dunedin City	Remote	Remote	Ext Remote	Probable	Probable	Probable
Otago	Remote	Remote	Ext Remote	Probable	Probable	Probable
Southland	Remote	Remote	Ext Remote	Probable	Probable	Probable
Invercargill City	Remote	Remote	Ext Remote	Ext Remote	Probable	Probable

9.4 Risk exposure ratings

The total risk exposure in each area or region is then assessed by combining the information in the two tables. Risk exposure is the product of the likelihood and consequence ratings.

The following numerical values have been assigned to the descriptions used in the tables:

- The relative **likelihood ratings** are generally similar in proportion to the exceedance periods that can be inferred from the above table.
- The relative **consequence ratings** are similar to those used in other studies undertaken by Maunsell where natural hazard events are being assessed.

Likelihood:		**Consequence:**	
Frequent	64	Insignificant/nil	1
Probable	16	Minor	8
Remote	4	Major	50
Extremely remote	1	Critical	250
		Catastrophic	1000

Tables 9.4 and 9.5 present the results of assigning these values to the relative ratings shown in the previous diagrams.

To demonstrate the combined effect of risk exposure and relative population size, the totals are also adjusted to take account of the percentage distribution of population among the different areas.

Table 9.4 Relative risk exposure ratings.

RELATIVE RISK EXPOSURE RATINGS								
Area				**Hazard Event**				
	Seismic	**Coastal**	**Volcanic**	**Landslide**	**Flooding**	**Snow / Ice**	**Totals**	**Population Modified**
Northland	50	200	8	128	800	1	1059	39
Auckland (Region)	1000	200	1000	128	200	1	2401	763
Waikato	1000	32	1000	128	800	32	2864	271
Taranaki	200	32	1000	128	800	4	2036	55
Bay of Plenty	1000	200	1000	128	800	4	3004	120
Rotorua	1000	1	1000	128	800	128	2929	67
Gisborne	1000	200	200	128	800	4	2204	25
Hawkes Bay	1000	200	200	128	800	128	2328	87
Manawatu/Wanganui	1000	32	200	128	800	800	2832	163
Wairarapa	1000	32	8	128	800	32	1872	37
Wellington	4000	32	8	128	800	32	4872	453
Nelson/Tasman	1000	32	1	128	800	32	1865	43
Blenheim	1000	200	1	128	800	128	2129	21
West Coast	4000	32	1	128	800	32	4865	38
Christchurch	1000	200	1	128	200	800	2201	220
North Canterbury	1000	200	1	128	800	800	2801	42
South Canterbury	200	200	1	128	800	800	2001	26
Dunedin	200	200	1	128	800	800	2001	60
Otago	200	32	1	128	800	800	1833	35
Southland	200	32	1	128	800	800	1833	22
Invercargill	200	32	1	8	800	800	1833	22

Table 9.5 shows the rankings based on the combined risk exposure and population factors, with Wellington having the highest rating and Invercargill City the lowest.

Table 9.5 Relative risk exposure ratings – ranked.

RELATIVE RISK EXPOSURE RATINGS - RANKED								
Area	Hazard Event							
	Seismic	Coastal	Volcanic	Landslide	Flooding	Snow / Ice	Totals	Population Modified
Auckland (Region)	1000	200	1000	128	200	1	2401	763
Wellington	4000	32	8	128	800	32	4872	453
Waikato	1000	32	1000	128	800	32	2864	271
Christchurch	1000	200	1	128	200	800	2201	220
Manawatu/Wanganui	1000	32	200	128	800	800	2832	163
Bay of Plenty	1000	200	1000	128	800	4	3004	120
Hawkes Bay	1000	200	200	128	800	128	2328	87
Rotorua	1000	1	1000	128	800	128	2929	67
Dunedin	200	200	1	128	800	800	2001	60
Taranaki	200	32	1000	128	800	4	2036	55
Nelson/Tasman	1000	32	1	128	800	32	1865	43
North Canterbury	1000	200	1	128	800	800	2801	42
Northland	50	200	8	128	800	1	1059	39
West Coast	4000	32	1	128	800	32	4865	38
Wairarapa	1000	32	8	128	800	32	1872	37
Otago	200	32	1	128	800	800	1833	35
South Canterbury	200	200	1	128	800	800	2001	26
Gisborne	1000	200	200	128	800	4	2204	25
Southland	200	32	1	128	800	800	1833	22
Invercargill	200	32	1	8	800	800	1833	22
Blenheim	1000	200	1	128	800	128	2129	21

The tables show the relative risk exposure ratings for each hazard separately. In addition, and for the purposes of this study only, a combined measure is calculated as the sum of the hazard ratings.

The totals column provides a comparative picture of the total risk exposure to these natural hazards for each region/area, based on the relative ratings. It is acknowledged that simply adding across hazard events that have significantly different probabilities of occurrence and scales of impact may not be acceptable in terms of a pure risk management approach. However, the aim here is simply to obtain a high-level, subjective view of relative risk exposures on a regional basis.

9.5 Risk exposure and other indicators

The risk exposure ratings adjusted for population from section 9.4 have also been compared on a regional basis to:

- roading expenditure (Figure 9.2)
- share of the national economy (Figure 9.3).

There is some consolidation of the results to the regional level as there are more lifelines areas than regions.

9.5.1 Roading expenditure

The roading expenditure used is the total roading expenditure (state highway plus local roads) from the Land Transport NZ network statistics report for the 2004/05 year. It includes local authority expenditure.

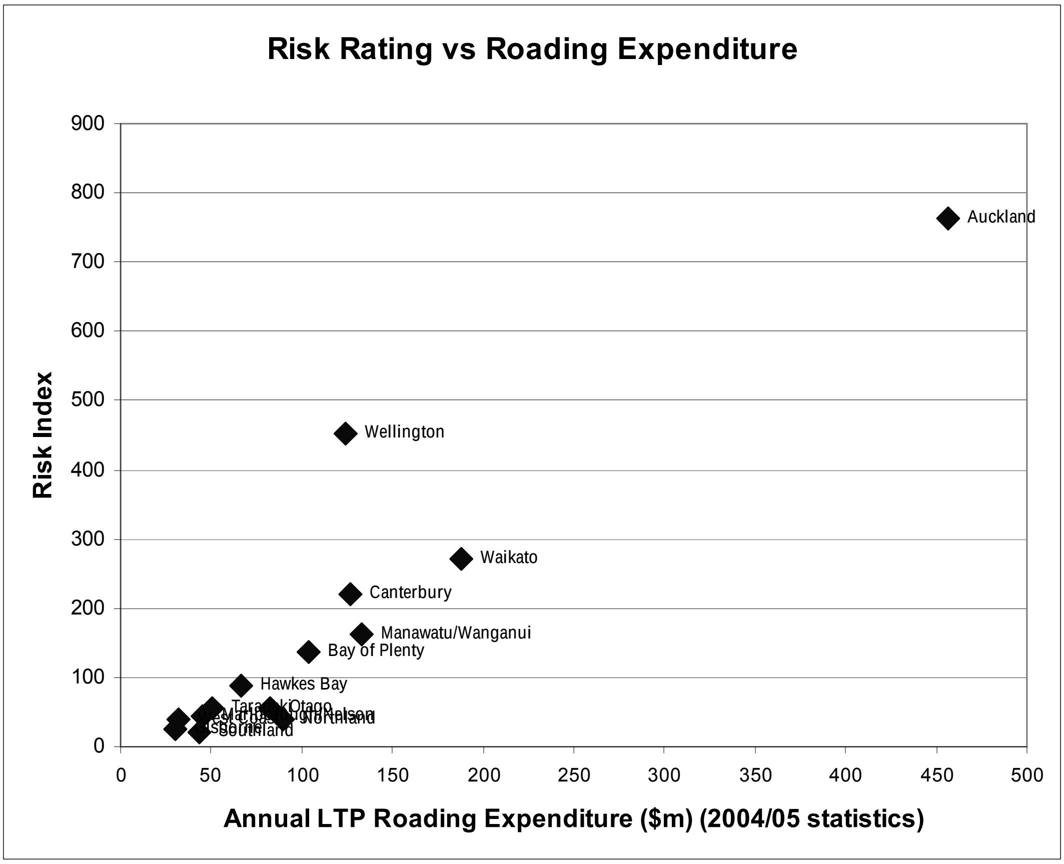
The expenditure in the Auckland region stands out and reflects that region's dominance in terms of traffic volume and the need for roading infrastructure.

The regions with a high level of expenditure should have a greater ability to fund works targeted at addressing the risk exposure from natural hazards. Also, when new capital investment and asset renewals works are being programmed, there is a certain level of 'resilience strengthening' that can be incorporated in the project. Those with low levels of expenditure and capital investment could find it more difficult to source funding and allocate it to reducing risk exposure to natural hazards.

Note also that other factors such as terrain and material costs will also influence a region's ability to fund improvements to at risk infrastructure.

9.5.2 Economy and population

The information for these graphs was obtained from the Department of Statistics website. The aim was to attempt to assess what was at risk in terms of economic and social capital on a regional basis. Again the Auckland region stands out with a significant amount to lose in both areas.



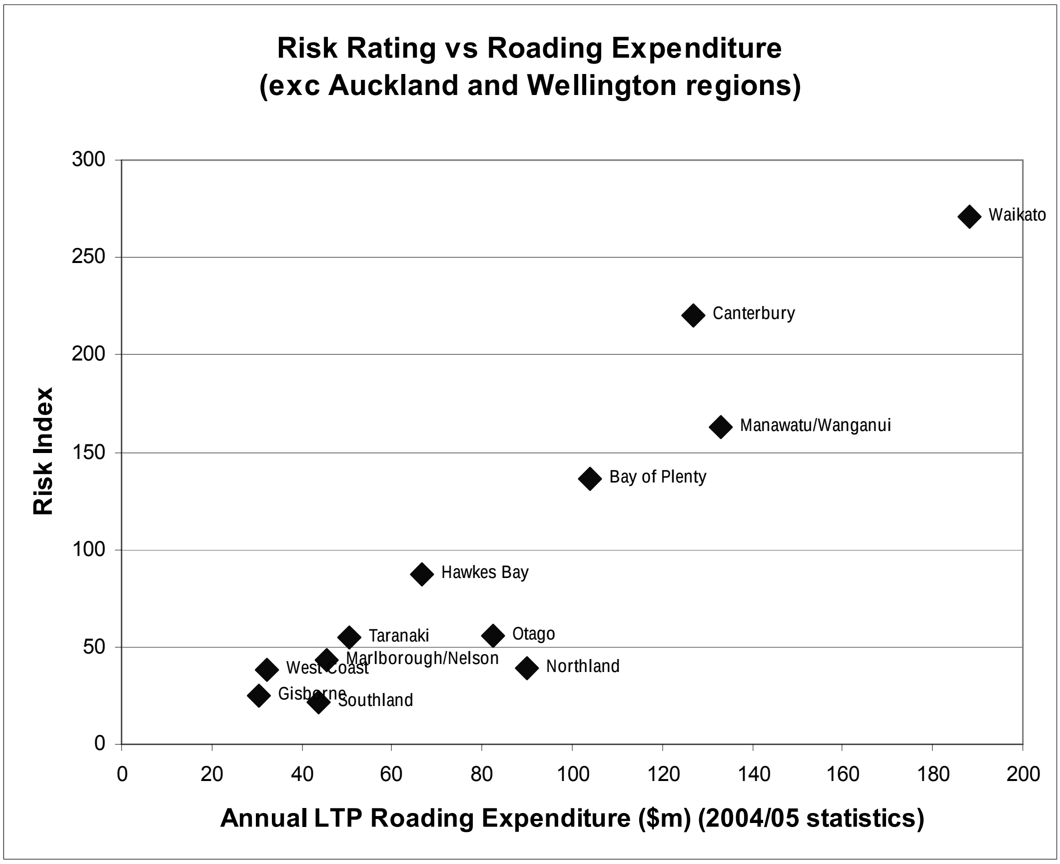
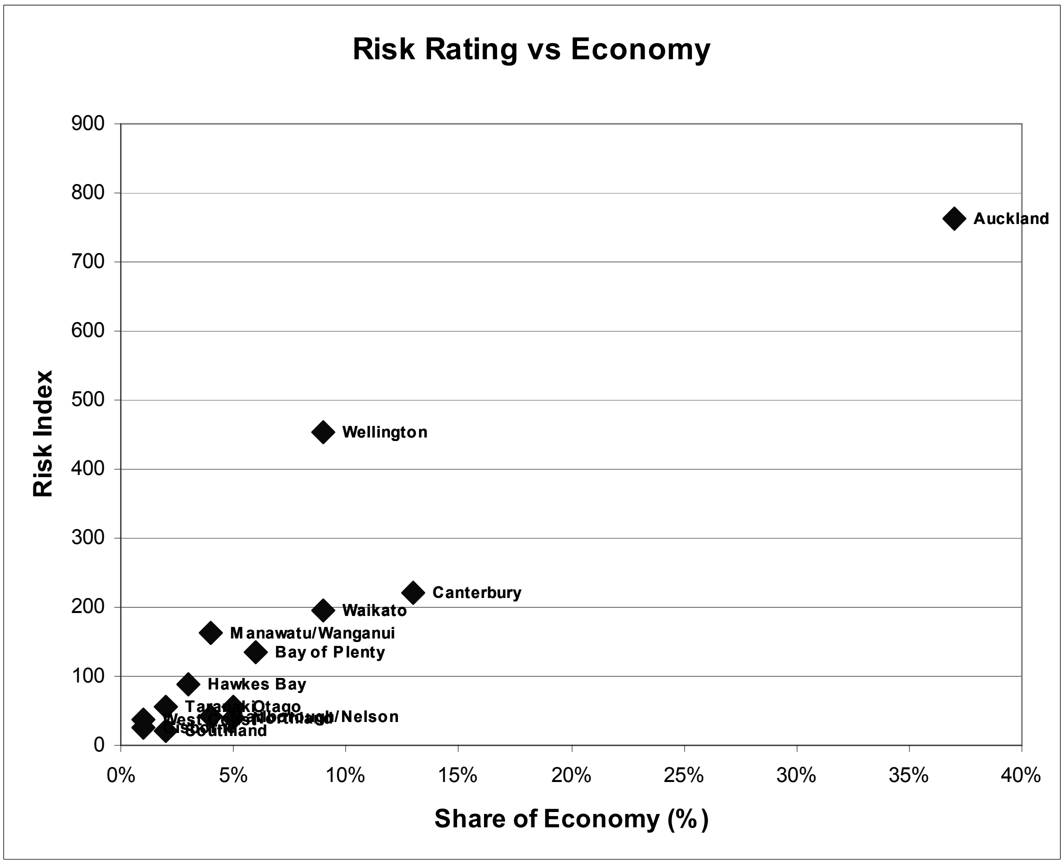


Figure 9.2 Graphs of risk exposure v roading expenditure by region.



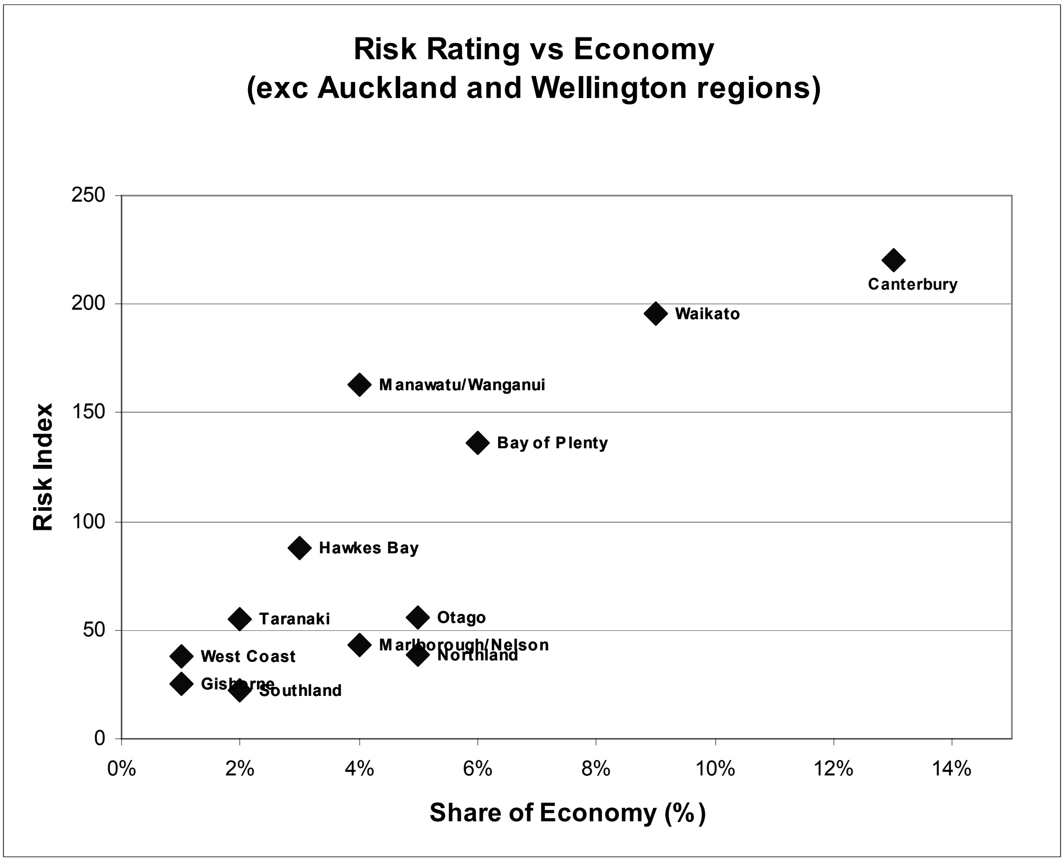


Figure 9.3 **Graphs of risk exposure v share of New Zealand economy by region.**

10 New Zealand lifelines current practice

10.1 Lifelines project development

The sequence of development of lifelines activity in an area typically begins with the establishment of a project, with project members representing lifeline utilities (covering transportation, water supply, wastewater, power and telecommunications), hazard experts and emergency services representatives.

Typical project objectives would be to:

- identify the vulnerability of engineering lifeline services to damage from natural hazards
- identify practical engineering strategies for reducing the risk or impact of such damage and for providing for reinstatement following such events
- communicate the issues to people involved in the management of these services and to raise public awareness
- establish processes in the constituent lifelines organisations to ensure ongoing commitment and funding for implementation of the strategies, such as inclusion in LTCCPs.

Typical project tasks would include:

- detailed consideration of the natural hazards likely to occur in the area
- commissioning research into the natural hazards
- ranking of natural hazard events
- study of the vulnerability of individual lifeline services, such as:
  - roading
  - other transport modes (air, sea, rail)
  - water supply
  - sewerage
  - stormwater
  - electricity supply
  - telecommunications
  - petroleum and gas suppliers
  - key community facilities (hospitals etc)
- study of the interdependencies between these services
- detailed assessment of key transport routes
- developing strategies for reducing the risk
- providing details of key projects targeted at minimising risk
- producing report(s) of findings and recommendations.

Benefits of undertaking such a project not only include the resulting findings, but also the information sharing process between utilities and the quality of the working relationships that result.

In the regions where lifelines projects have been completed there should be a good understanding of the key natural hazards likely to occur. There should also be a good understanding of what components of each utility lifeline are the most vulnerable and what could or should be done to improve their resilience.

10.2 Lifelines group establishment

The next phase of development is the formation of a lifelines group, once the initial project has been completed. This phase is intended to ensure an ongoing focus on lifelines activities, providing support and encouragement to lifelines organisations in undertaking mitigation work, continuing their involvement, and developing new lifelines initiatives. It also provides a mechanism for 'reporting back' on progress, and maintaining cross-sectoral awareness and relationships with a linkage to the new civil defence and emergency management (CDEM) groups in some areas.

10.3 Comparative assessment of lifelines activities

During 2004, the coordinators of the 17 lifelines groups and projects around New Zealand were asked to complete a questionnaire to give their perspective of the level of understanding of natural hazards and the level of lifelines organisation and preparedness with an emphasis in relation to the roading network. It should be noted that the coordinators came from a wide range of backgrounds and this may have influenced the way they have responded to different questions.

Refer to Appendix A for a copy of the questionnaire and details of the responses.

Completed questionnaires were returned from 15 of the 17 coordinators giving a good coverage of the country and a reasonable split between urban and rural areas.

Overall the responses were very positive. A summary is provided below.

Table 10.1 Summary of questions and responses from lifelines coordinators' survey.

#	Question	Summarised response
2	What work has been done on hazard identification?	All indicated that hazards were well identified and that the likelihood of occurrence had been assessed by experts.
3	What is the group's understanding of the impact of a natural hazard?	All except one had a broad understanding of the impact of a natural hazard on the roading network, and for half this was based on a systematic assessment by experts and roading specialists.
4	What is your view of RCAs' understanding of the impact of a natural hazard?	All except one considered that the RCAs had a good understanding of the impact of a natural hazard and for half this was based on a systematic assessment.

5	Understanding of the consequences of a road network failure.	The majority indicated that the consequences of a roading network failure on both the roading network and other utilities in their project area were well understood. There was a lower level of understanding of the impacts on other utilities.
6	RCAs' level of understanding of the consequences of a road network failure.	They believed that there was a similar level of understanding within the RCAs.
7	What action has been taken to mitigate the impact of a natural hazard?	The majority (10 of 14 that answered this question) believed that while some actions had been planned to mitigate the impact of a natural hazard there had been very limited implementation.
8	Amount of expenditure specifically targeted at improving the road network resilience.	Their perception of the amount of expenditure targeted at making the roading network more resilient to a natural hazard varied widely. For most there was minimal expenditure. Five respondents did not know.
9	Do RCAs keep the lifelines group informed about mitigation works?	An even split between yes and no.
10	Are AMPs being used by RCAs to plan mitigation works?	Half indicated that AMPs were being used for planning and prioritising mitigation works. The balance did not know.
11	What is your view of the relationship between RCAs and lifelines agencies?	Most indicated that there was evidence of a relationship between lifelines people and the RCAs, and for some a strong working and sharing relationship.
12	What is your view of the level of community awareness of natural hazards?	The majority indicated that their communities were aware of the impact of natural hazards but none indicated a high level of awareness.
13	What is the level of technology use for lifelines purposes?	GIS is being used (or planned to be used) by many organisations to record hazard information with some use for assessment.
14	How will the lifelines knowledge and experience be used under the CDEM Act?	How lifelines organisations would be used under the CDEM Act drew a wide range of responses. Most coordinators indicated that they were a part of or were contributing to the CDEM group and the planning being done by those groups.
15	How do you rate the RCAs' ability to respond in a major natural hazard event?	Range was 2 to 4 in a scale of 1 (inadequate) to 5 (exceptional)

The following conclusions could be drawn from the survey:

- In the regions where lifelines groups have been established with a project either completed or underway, natural hazards have been well identified and the likely impact on the roading network is well understood.
- The impact that a roading network failure would have on other utilities is also well understood.
- Some lifelines coordinators indicated that there has been limited action, either planned or taken, to mitigate against the impact of a natural disaster. (The follow up question from

this with the RCAs is why – is it considered unimportant, funding shortfalls, or just too hard?).

- Apart from two regions the perception is that very little funding has been specifically targeted at improving the roading network's resilience to natural disasters. (The question for follow up is why – should more be spent and if so, what could be done to improve resilience, or are mitigation measures part of general roading improvements?).
- While 50% of responses indicated that RCAs kept the lifelines organisations informed of mitigation work the feeling from the responses to this question and the one on the use of AMPs is that there is limited communication and/or not a good understanding of what different groups are doing. (This needs follow up. Is it personnel changes and a lack of continuity, workloads, or is it not seen as important?).
- While most lifelines groups were very involved in the new regional CDEM groups, there is a level of uncertainty about the ongoing relationship between lifelines groups and the groups established under the CDEM Act.

10.4 Comparison of lifelines activity

In order to compare lifelines activity on a national basis, activity was initially identified at four levels, based on the information obtained during Phase 1. This was supplemented with survey feedback and input by the project team, as well as information from National Lifelines Conferences, at which reports are received from each lifelines area. The following tables summarise the position at that time.

In general terms, lifelines activity has been focused in the areas of greater risk. For those areas where the risk exposure is lower, there is a significant variation in the level of lifelines activity.

Note that lifelines groups and activities are not necessarily set up on a regional basis so the list includes a mix of regional and local authorities.

Table 10.2 Level 4 – initial project completed. Lifelines group is established and active.

Lifelines area	2004 Conference update	2005 Conference update
Auckland	Business Plan 2004–06 established Various projects identified and reported on	24 funding members and wide representation, quarterly meetings Several project reports completed and published Further projects planned/underway.
Hawkes Bay	Ongoing meetings of group CDEM responsibilities for utilities absorbed by group	Maintained activity CDEM Coordinating Executive Group (CEG) sub-committee status, and also independent Lifelines utilities survey undertaken Disaster resilience workshop Further projects planned
Wellington	Various activities/projects identified and/or underway These include response protocols for lifeline utilities, application of GIS by lifeline utilities, emergency communications	Projects from 2004 completed Emergency event management and transportation planning discussions with Land Transport NZ Charter for WeLG prepared
Wairarapa	Monitoring mitigation measures and continuing with hazards investigations Bridge scour screening project planned	Priority emergency route maps prepared – will include bridge scour risk, for which work has been continuing through Victoria and Canterbury Universities
Christchurch	Annual monitoring of activity by utilities Regional workshops Desire to see engineering lifelines integrated in AMPs and LTCCPs	Monitoring ongoing Technology failure workshop held Widened to Canterbury Engineering Lifelines Group CELG manager is a member of (CEG), while CELG itself is a separate group
Dunedin	Hazards reviewed at annual group meeting Monitoring of utility activities Workshops	Annual group meeting – review key hazards and utility work
Invercargill	Project report completed	Nil return

Table 10.3 Level 3 – project set up/underway.

Lifelines area	2004 Conference update	2005 Conference update
Northland	Inaugural meeting March 2004 Priority utility sites project initiated Coordinating with CEG re hazards information	16 organisations now participating Priority utility sites project completed
Waikato	Project establishing	Steering group active, newsletters published Focus on hazard identification Propose to support asset managers with risk management aspects of AMPs
Manawatu-Wanganui	Project vulnerability analysis and impact assessment work completed	Lifelines report completed Lifelines group formed as an advisory group under CDEM group
Nelson/Tasman	Report nearing completion	Nil return

Table 10.4 Level 2 – initiating group and/or project may be established but limited action.

Lifelines area	2004 Conference update	2005 Conference update
South Canterbury (Timaru)	Nil return	Now part of Canterbury Lifelines Group
Rotorua	Nil return	Nil return
Western Bay of Plenty/Tauranga	Project on hold	Reactivated July 2005 Hazards vulnerability analysis undertaken Hoping to establish group and include all BOP area
West Coast (SI)	Hazards analysis by Grey District, followed by lifeline utilities meeting Plan to establish lifelines group under CDEM group plan	Report commissioned on Alpine Fault and extending to other districts
Taranaki	Lifelines activity undertaken via an advisory committee to CEG	Lifelines activity undertaken via an advisory committee to CEG

Level 1 - nothing much happening at all (at present).

Marlborough
Otago
Southland
Gisborne
Eastern Bay of Plenty

11 Transport system resilience

There is an expectation that 'disaster resilience summaries' will be prepared by lifeline utility organisations to assist regional CDEM groups in planning for disaster events. Such information is also important to asset managers in planning future infrastructure renewals, asset strengthening and capital improvement works. Incorporating risk in the investment decision-making process is desirable practice; however, there is a question of how this should be done in a way that maximises or optimises long-term community welfare across social, environmental, economic and cultural dimensions.

The development of a systematic resilience based framework if used appropriately can provide asset managers with a tool that can be used to better understand resilience, network weaknesses, and to assist identify priorities for risk investigation and mitigation.

11.1 Measures of resilience

Resilience relates to the ability of a roading network to continue to support the community and meet the community's social, economic and environmental needs, following a major hazard event. This section identifies possible measures for transport system resilience that could be used in comparing the response of different networks to different hazard events. Such measures could then be further developed and used in emergency management planning and in AMPs.

Two quotes from the Wairarapa Engineering Lifelines report describe this concept of resilience rather well.

> *The most important role of the transport system in an emergency is to provide adequate internal and external links for emergency service providers during and immediately after an event.*
>
> *The quality and resilience of the transport system will determine how long an area will need to be self-reliant.*

Parameters for assessing resilience could include:

- the **resistance** of the asset itself to a hazard event. This could be assessed by how much of the network might be damaged and/or unusable after a hazard event – this introduces the concept of 'damage assessment ratios'
- the **network layout** and whether there are alternative routes. If there are alternatives, then the road network's function may be able to continue, albeit on a restricted basis
- the **volume** of traffic in relation to the level of service offered by the road. The greater the impact of a hazard event on traffic, the lower the level of resilience
- the **time** that it would take to restore the road network and allow traffic back.

These are now considered in turn.

11.1.1 Resistance

There are several means by which a road network may be disrupted, such as:

- the collapse of or damage to a bridge or structure that subsequently blocks traffic access
- direct damage to the road carriageway through subsidence, wash-out, or other damage by other services failing that also blocks or disrupts access
- the effect of a related event, such as a wild-fire or major incident that prevents the road being used.

The resistance of specific parts of a road network to hazard events can be assessed by considering factors such as:

- design standards of the asset – eg seismic standards for bridges that protect the asset
- the age or condition of the asset in relation to its original design. An asset near the end of its life may be more likely to fail as a result of a hazard event than a modern or new asset
- geological conditions – such as the underlying strata, groundwater, erosion potential, etc. These may make the asset more vulnerable to the hazard event
- topography – whether flat, hilly, or mountainous terrain. This could also include low-lying or coastal roads subject to flooding or storm-surge events
- the presence or otherwise of vulnerable services in the road corridor – such as overhead power and telecommunication lines or high pressure water supply pipelines. Such services could fail during a hazard event such as an earthquake, snow or wind.

These types of parameters can be scored and assembled into a matrix alongside critical assets such as bridges and arterial roads, which could then be used as part of the risk assessment procedure in an AMP. Each of these factors could affect resilience to a greater or lesser degree, and this could be modelled along with the other parameters discussed below. Such a model would need to use these and other appropriate factors and link them to 'damage assessment ratios' for specific hazard events. Initially, this could be done subjectively using staff and contractor knowledge, with data being built up over time based on experience or specific research.

Bridges in a road network are likely to be the key component which should be considered as a matter of initial priority. If a high proportion of bridges are found to be at risk from hazard events then the network has a low level of resistance.

Transit NZ has completed a seismic screening programme for state highway bridges and this identified priorities and preferred actions in terms of linkage retrofit, seismic strengthening and further investigations required. A substantial amount of improvement work has been completed. Work is also underway in developing scour screening methodology and applying this in the risk management process.

Information is available on the seismic resistance of other bridge assessments undertaken as part of regional lifelines project work (eg Christchurch, Wairarapa, Hawkes Bay, Wellington, Auckland). The assessments are probably different although the Wairarapa project has used the preliminary procedures laid out in the Transit NZ manual *Seismic screening of bridges* (1998). It should be possible to correlate the assessments or rework assessments of the more important bridges in the lifelines studies.

11.1.2 Network layout

Network layout is frequently dictated by topography. Urbanisation and the intensity of land use also have a significant influence. From a subjective perspective, three discrete types of network layout can be defined:

- linear – essentially only one key route with very few if any alternatives
- dispersed – a limited number of alternative routes exists, but they are some distance apart
- grid – a large number of alternative routes is available should one fail.

In terms of functionality, the ‘grid’ network is the most resilient simply because of the greater level of redundancy available. The type of network (or sub-network) in an area can be rated and incorporated in a ‘resilience model’.

Most New Zealand regional road networks would fall into the dispersed category. Some such as in Wellington, the West Coast and Gisborne would be considered linear, with those in Canterbury and Southland tending more to a grid layout.

11.1.3 Traffic volumes

A key assumption is that the greater the level of traffic disruption, the less resilient is the road or network being considered – because of the consequential impact on the community. Therefore, heavily trafficked roads which are disrupted will have a more significant effect on the community than low-volume roads. Also, if a route has a low level of service, such as major congestion or capacity restraints, then a given hazard event or incident is more likely to result in major traffic disruption.

Such effects could also be included in a resilience model.

Factors used in the model could be the total volume or volume per lane km, and/or the current level of service, such as the *Highway capacity manual* (TRB 2000) A to F rankings used in traffic modelling work. The lower the level of service then the less resilient the network is likely to be to a hazard event. A high volume **and** low level of service could indicate a low resilience which would be of concern, particularly if other factors such as topography and network layout further decreased resilience.

Note also that in a major hazard event, leading to a civil defence emergency, traffic volume may be less important than the other two parameters as non-essential users can be directed to ‘stay off the road’.

11.1.4 Recovery time

The length of time to recover from the event and fully restore services will have direct social and economic impacts. It is important to consider these together with resilience. For example, a bridge servicing a significant area but which takes many months to restore, will lead to different outcomes than a road which can be cleared and normal traffic resumed within days to weeks. Recovery time is, therefore, an important resilience parameter.

11.1.5 Typical examples

A **dispersed or grid** network with only a small percentage of bridges at risk from hazard events, in good country, and providing a good level of service at peak traffic flows, could be considered to have a high level of resilience.

However, a **linear** network with a similar or greater percentage of at-risk bridges would be considered to have only a low to medium resilience. If the level of service was already poor then the resilience would drop further.

It may be appropriate to initially use the state highway network in assessing the level of resilience in different parts of the country, utilising comprehensive bridge seismic screening information along with a good understanding of other at-risk areas. This network carries a very high proportion of the total volume of vehicles and would be considered the key road transport component by most communities.

11.2 Level of investment

The feedback from the survey of lifelines coordinators indicated that apart from one or two regions there was very limited investment that had the sole purpose of improving the roading network's resilience to natural hazards. This is explored in more detail in the Phase 3 survey of RCAs, as many new works or renewals do assist with improving the resilience of the network even if that is not the primary purpose of the work. For example the Woolston-Burwood expressway in Christchurch was a network improvement project that included a new bridge across the Avon River with additional seismic strengthening. This has significantly improved the network's overall resilience to an earthquake event.

The alternative, at this stage, is to consider the total capital expenditure on roading infrastructure and assume that the proportion of this that assists with improving network resilience is reasonably constant throughout New Zealand. Information on capital expenditure is available from Land Transport NZ's roading statistics.

Expenditure by region for 2004/05 is shown in Figure 11.1 below. This includes the local authority share.

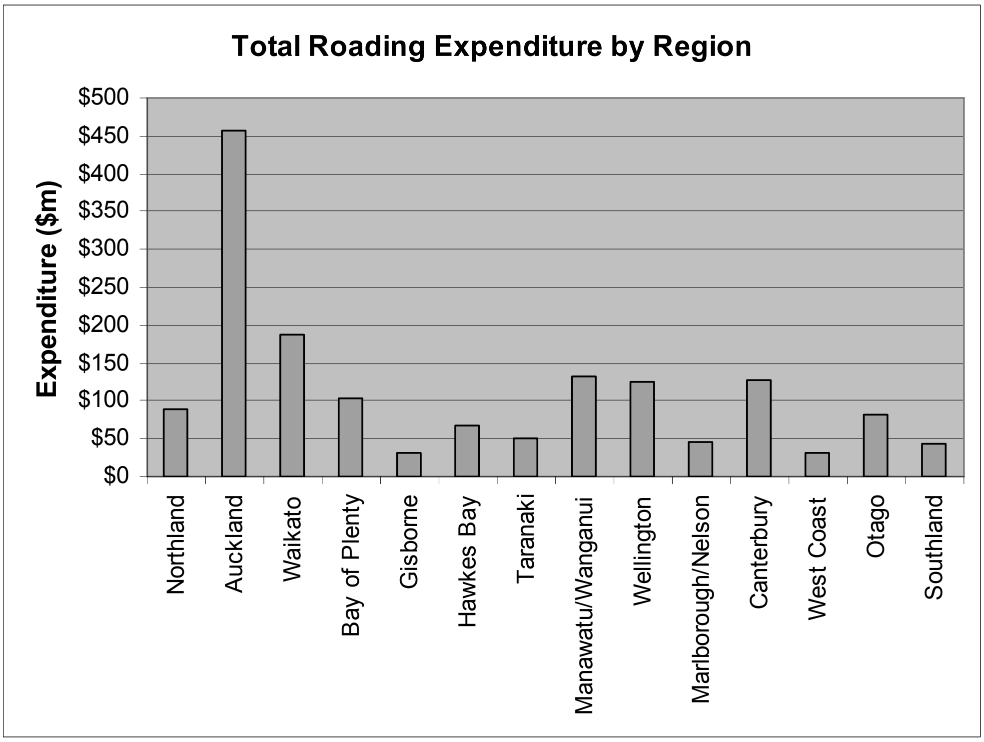


Figure 11.1 Roading expenditure by region taken from Land Transport NZ statistics for the year ending 30 June 2005.

These concepts are further developed in Part two of this report (Phases 3 and 4) drawing on further information from RCAs.

11.3 Damage assessment ratios

The use of damage assessment ratios for quantifying the extent of the damage to infrastructural assets can provide a broad picture of the consequences of natural hazard events. This information can indicate how badly an infrastructural network could be damaged in a given event, and thus help emergency management planners understand the potential vulnerability of a community to that event.

While this type of analysis has been used overseas, for example in the United States, there has been limited use in New Zealand. Good data is needed on the likely failure rates of different assets and material types in different conditions, which is then combined with spatial data relating to the hazard event. Failure data is not easy to obtain, given the many factors that can affect the failure mechanism. Nevertheless, broad assessments can be made and future efforts should be targeted at improving the level of understanding of how assets will fail under different conditions – and the extent of the failure.

In terms of transport infrastructure, activities such as lifelines assessments of bridge vulnerability and seismic screening of bridges provide data about relative resilience to hazard events. This work, together with gaining a better understanding the implications for communities, needs to be further progressed through initiatives such as Priority Routes projects.

11.4 Resilience and community outcomes

The resilience of assets, or a network, to hazard events has a direct impact on community well-being. This will depend on the consequences asset failure has on traffic flows and how this affects the community – and this must be first understood.

There may be the following disruptions:

- social – restricted accessibility; unable to reach people; education and health disrupted
- economic – businesses unable to trade or move goods
- environmental – direct damage, such as sedimentation of watercourses.

A resilience model should incorporate consequence linkages to such factors and thus quantify in some way the effect on a council's stated community outcomes.

Further consideration was given to this in the next phase of the research.

12 Conclusions on future development

Phase 2 of the project has provided comparative information on the level of activity of the different lifelines organisations and the lifeline coordinator's view of their region's preparedness, with an emphasis on the roading network.

A broad assessment has been made of the relative probability, consequences and the level of risk exposure on a regional basis across New Zealand. Numerical ratings were assigned to each type of hazard and its consequence and these were combined to form an overall risk exposure rating.

This risk exposure has been compared with the level of lifelines activity, total roading expenditure, population and the regional share of the economy. This rough order comparison indicates that lifelines activity has been focused across areas with a wide range of risk. While the degree of lifelines management is at a high level in areas with greatest risk there are some at-risk areas where there has been limited lifelines activity. Possible reasons for this are explored with RCAs in the Phase 3 survey.

The survey of lifelines coordinators for all lifelines groups and projects in New Zealand indicated that where lifelines has been established the natural hazards have been well identified, and the likely impact on roading networks and the subsequent impact on other utilities are well understood. Overall however, there was a view that there had been very limited action either planned or undertaken to mitigate assets against the impact of a natural disaster.

Finally, concepts for assessing and comparing transport infrastructure resilience have been identified and could be considered for further development in risk management and asset management planning.

13 References

This reference list excludes documents/papers obtained from internet sites identified in section 2.

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13.1 Website research

Information was obtained from a search of regional (and unitary) authority websites. The following comments summarise the type of information found relating to lifelines and civil defence.

Regional council	Web address	Comments
General		The majority of regional council sites contain good public information on and a good description of hazard types. Many also have links to other regional councils and to other hazard info sites Information is difficult to find on some sites as it is under region or regional services
Northland	www.nrc.govt.nz	Links to NIWA, MetService, GNS etc No references to lifelines
Auckland	www.arc.govt.nz	Link to lifelines project work plus research into volcanic hazards
Waikato	www.ew.govt.nz	References to all hazards including tsunami and volcanic ashfall Lifelines described but no links
Bay of Plenty	www.boprc.govt.nz	Good hazard description particularly for seismic and volcanic. Good maps No lifelines links. (Note project groups are in Western Bay of Plenty and Rotorua District Councils)
Hawkes Bay	www.hbrc.govt.nz	Link to lifelines project (Facing the Risks) – pdf file Also pdf file on recent work on coastal hazards.

		(Out for public comment)
Taranaki	www.trc.govt.nz	No link to lifelines Information focused on flooding and volcanic activity
Manawatu	www.horizons.govt.nz	Refers to lifelines project. See pdf for newsletter
Wellington	www.wrc.govt.nz	Link to lifelines Good information on recently completed Wairarapa lifelines project
West Coast	www.wcrc.govt.nz	Very limited Information, no reference to lifelines
Canterbury	www.ec.govt.nz	Under civil defence. Reference to lifelines work and link to *Risk and realities* (no longer current). Not a great site
Otago	www.orc.govt.nz	Nothing found on CD or lifelines
Southland	www.src.govt.nz	Nothing found on CD or lifelines
Gisborne	www.gdc.govt.nz	Nothing found on CD or lifelines
Tasman	www.tdc.govt.nz	Nothing found on CD or lifelines
Nelson	www.ncc.govt.nz	Nothing found on CD or lifelines
Marlborough	www.marlborough.govt.nz	All extremely limited info on CD and no reference to lifelines

13.2 Other website references

Other useful websites were accessed for information:

www.govt.nz	For an A to Z of local and central government organisations
www.naturalhazards.net.nz	Website for Natural Hazards Centre, a joint venture between NIWA and the Institute of Geological and Nuclear Sciences. Quarterly newsletter and links to a large number of research projects. Links to online monitoring sites
www.mcdem.govt.nz	Ministry of Civil Defence & Emergency Management. Site has lifelines page with link to groups but only two at present.
www.caenz.com	Centre for Advanced Engineering. Information more about risk management than lifelines

Appendix A: Survey of lifelines coordinators

The following questions were incorporated in a written survey to 17 lifelines coordinators throughout the country. Follow-up with four initial non-respondents was undertaken. Fifteen responses were received, with incomplete or missing responses from Wairarapa and Tauranga.

1. What is the level of lifelines activity in the region?
    1. None at all
    2. Initiating – small core with gaps and no formal agreed plan
    3. Project – with cross sectoral input and a nominated Project Manager
    4. Group – with cross sectoral membership and a nominated project manager
    5. If there is more than one group/project is there any sharing of work or co-ordination of research at a regional level.

	Northland	Auckland	Waikato	Rotorua	Hawkes Bay	Taranaki	Manawatu-Wanganui	Wellington	Nelson	West Coast	North Canterbury	Christchurch	South Canterbury	Dunedin	Invercargill
1															
2			✔							✔			✔		
3				✔		✔	✔				✔		✔		✔
4	✔	✔			✔			✔	✔			✔		✔	
5												✔			

2. What work has been done on hazard identification?
    1. Hazards not yet formally identified.
    2. Hazards known to exist but not comprehensively assessed for the purpose.
    3. Hazards identified and described and their likelihood/probability of occurring assessed by experts in their field.

	Northland	Auckland	Waikato	Rotorua	Hawkes Bay	Taranaki	Manawatu-Wanganui	Wellington	Nelson	West Coast	North Canterbury	Christchurch	Timaru	Dunedin	Invercargill
1	✔														
2						✔				✔			✔		
3		✔	✔	✔	✔	✔	✔	✔	✔		✔	✔	✔	✔	✔

3. What is **the group's** understanding of the impact of a natural hazard (on the roading network)?

    1. Very limited knowledge of the effects of a natural hazard on the roading network
    2. Effects broadly understood but they have not been analysed systematically
    3. Effects understood following systematic analysis by RCAs.

	Northland	Auckland	Waikato	Rotorua	Hawkes Bay	Taranaki	Manawatu-Wanganui	Wellington	Nelson	West Coast	Hurunui	Christchurch	Timaru	Dunedin	Invercargill
1							✔								
2	✔		✔	✔				✔		✔			✔		✔
3		✔			✔	✔			✔		✔	✔		✔	

4. What is **your view of the RCAs' level** of understanding of the impact of a natural hazard on the roading network in your area. Please differentiate between RCAs if you perceive that there are significant differences.

    1. Limited knowledge of the effects of a natural hazard on the roading network
    2. Effects broadly understood but not analysed systematically
    3. Effects understood and systematically analysed

	Northland	Auckland	Waikato	Rotorua	Hawkes Bay	Taranaki	Manawatu-Wanganui	Wellington	Nelson	West Coast	Hurunui	Christchurch	Timaru	Dunedin	Invercargill
1							✔	✔							
2	✔	✔	✔	✔	✔			✔		✔	✔		✔		
3					✔	✔			✔			✔	✔	✔	✔

5. What is **the group's** understanding of the consequences of a roading network failure due to a natural hazard in your region?

a. Effect on roading network	**b. Effect of roading network failure on utilities**
1. Very limited knowledge	1. Very limited knowledge
2. Some knowledge	2. Subjective understanding
3. In depth knowledge	3. Understanding informed by systematic analysis or assessment
4. In depth, plus documented understanding of wider social and economic impacts	

Question 5a

	Northland	Auckland	Waikato	Rotorua	Hawkes Bay	Manawatu-Wanganui	Taranaki	Wellington	Nelson	West Coast	Hurunui	Christchurch	Timaru	Dunedin	Invercargill
1						✓									
2	✓	✓	✓					✓		✓			✓		
3		✓		✓			✓	✓	✓		✓	✓			✓
4					✓							✓		✓	

Question 5b

	Northland	Auckland	Waikato	Rotorua	Hawkes Bay	Manawatu-Wanganui	Taranaki	Wellington	Nelson	West Coast	Hurunui	Christchurch	Timaru	Dunedin	Invercargill
1	✓					✓									
2		✓	✓				✓	✓		✓		✓	✓		
3				✓	✓				✓		✓	✓		✓	✓

6. What is **your view of the RCAs' level** of understanding of the consequences of a roading network failure due to a natural hazard.

Effect on roading network	**Effect of roading network failure on utilities**
1. Very limited knowledge	1. Very limited knowledge
2. Some knowledge	2. Subjective understanding
3. In depth knowledge	3. Understanding informed by systematic analysis or assessment
4. In depth, plus documented understanding of wider social and economic impacts	

Question 6a

	Northland	Auckland	Waikato	Rotorua	Hawkes Bay	Taranaki	Manawatu-Wanganui	Wellington	Nelson	West Coast	Hurunui	Christchurch	Timaru	Dunedin	Invercargill
1							✓								
2	✓		✓							✓			✓		
3		✓		✓		✓		✓	✓		✓	✓			✓
4					✓							✓		✓	

Question 6b

	Northland	Auckland	Waikato	Rotorua	Hawkes Bay	Taranaki	Manawatu-Wanganui	Wellington	Nelson	West Coast	Hurunui	Christchurch	Timaru	Dunedin	Invercargill
1							✓								
2	✓	✓	✓					✓		✓			✓		
3				✓	✓	✓			✓		✓	✓		✓	✓

7. What action has been taken to mitigate the impact of a natural hazard on the roading network in your region?

1. No action taken
2. Some actions planned for but limited implementation
3. Benefits and costs have been assessed and actions programmed.
4. Major roles have been addressed.

	Northland	Auckland	Waikato	Rotorua	Hawkes Bay	Taranaki	Manawatu-Wanganui	Wellington	Nelson	West Coast	Hurunui	Christchurch	Timaru	Dunedin	Invercargill
1															
2	✓	✓	✓		✓		✓	✓	✓	✓	✓		✓		✓
3				✓				✓				✓		✓	
4												✓			

8. What is **your perception** of the amount of expenditure that has been specifically targeted at improving the roading network's resilience to a natural hazard in your region?

1. $0-$50,000
2. $50,000-$200,000
3. $200,000-$500,000
4. $500,000-$1m
5. $1m-$2m
6. $2m +

	Northland	Auckland	Waikato	Rotorua	Hawkes Bay	Taranaki	Manawatu-Wanganui	Wellington	Nelson	West Coast	Hurunui	Christchurch	Timaru	Dunedin	Invercargill
1	✓		✓	✓							✓				
2													✓		✓
3							✓								
4															
5															
6								✓				✓			

9. Do RCAs keep the lifelines group in informed of any mitigation work they are planning?

- Yes / No
- Comment……

	Northland	Auckland	Waikato	Rotorua	Hawkes Bay	Taranaki	Manawatu-Wanganui	Wellington	Nelson	West Coast	Hurunui	Christchurch	Timaru	Dunedin	Invercargill
Y		✓	✓	✓	✓			✓				✓		✓	✓
N	✓				✓	✓	✓		✓	✓	✓	✓	✓		

10. How to your knowledge, are asset management plans or other key planning documents being used by RCAs to justify, prioritise and programme mitigation work?

- AMPs increasingly being used
- This is beginning to develop as part of asset planning and the LTCCP process
- Not being used
- Not enough linkage between lifelines work & AMPs yet. Not a priority but improving
- To a reasonable extent
- Fully utilised
- Not an extensive list of mitigation measures and probably more effective to incorporate mitigation measures within upgrades or projects. Certainly more chance of gaining approval.

11. What is your view of the relationship between the RCAs and other lifelines agencies? (Specify if there are differences between RCAs).

1. RCA has no formal or a weak relationship with other utilities and emergency services agencies, in relation to lifelines planning
2. Some evidence of a relationship but this is occasional and more reactive than proactive
3. Strong documented relationship with regular communication, information sharing, and joint meetings/workshops/exercises.

	Northland	Auckland	Waikato	Rotorua	Hawkes Bay	Taranaki	Manawatu-Wanganui	Wellington	Nelson	West Coast	Hurunui	Christchurch	Timaru	Dunedin	Invercargill
1	✓					✓									
2			✓	✓	✓	✓	✓	✓		✓	✓		✓	✓	
3		✓						✓	✓			✓			✓

12. What is your view of the level of community awareness about the impact of natural hazards on the roading network?

1. Community has little or no knowledge of the impacts of hazard events on the roading network
2. Community has some awareness
3. Community has a high level of awareness

	Northland	Auckland	Waikato	Rotorua	Hawkes Bay	Taranaki	Manawatu-Wanganui	Wellington	Nelson	West Coast	Hurunui	Christchurch	Timaru	Dunedin	Invercargill
1	✓		✓	✓			✓						✓		
2		✓			✓	✓		✓	✓	✓	✓	✓		✓	✓
3															

13. What is the level of technology use for lifelines purposes for the road network? (eg monitoring hazards or GIS for mapping of risk assets)

1. Not used in region
2. Planning to use
3. Used for the following applications:
    - Electronically prepared maps without full GIS capability along with spreadsheets. Planning to use more for social consequences.
    - Council has a project to use GIS for mapping priority routes and hazards.
    - GIS used for plotting all infrastructure (including roads) and hazard mapping.
    - Info for hazard identification put on GIS.
    - GIS representative of risks.
    - GIS used extensively.
    - Use of GIS and other software for general asset management. Not specific to lifelines.
    - GIS used to plot hazards and their effects on lifelines.
    - Hazards and networks on GIS used extensively. Risk assessment on a rational assessment basis using WELA Note 5.

	Northland	Auckland	Waikato	Rotorua	Hawkes Bay	Taranaki	Manawatu–Wanganui	Wellington	Nelson	West Coast	Hurunui	Christchurch	Timaru	Dunedin	Invercargill
1															
2	✔	✔	✔							✔		✔			
3				✔	✔		✔		✔		✔	✔	✔	✔	✔

14. In what ways will the knowledge and expertise of the lifelines group project be used under the Civil Defence and Emergency Management Act?

- As input to the RCAs' response planning under the Act and through lifelines project manager as rep on CDEMG and subcommittees.
- Our project has involved membership of the Civil Defence and Emergency Management Services who as users of roading have their own group.
- The work of the lifelines group will be invaluable in ascertaining the hazards and the risks in the environment to the community.
- Get utilities to have level of planning and preparedness to standard defined in the Act
- Will highlight key needs.
- Member of CDEMG. AELG represents all lifeline utilities for CDEM planning.
- Development of BCPs. Initiatives across the 4 'R's – particularly in reduction responses. The strategic section of the CDEM Plan will be used as a basis for future work and hazard research.
- The big question. Up to utilities themselves to draw on this information, which in turn requires their commitment of resources (staff). This does not happen easily or readily.
- Feeding all info into the CDEM control plan currently being written.
- Limited application because of informal arrangement of the project. Eventually greatest gains in fields of reduction and recovery planning.
- We are part of the CDEMG plan project team.
- Fully integrated as has been the case under the CD Act '83. All lifelines group members are incorporated in CDEMG structures for planning and response recovery.
- That is the next step to involve RCAs in CDEMG planning in regard to utilities. We have buy in by all mayors and participating RCAs.
- Use of information – planning, mitigation, response, and recovery aspects will contribute to resilience and clearer understanding of roles and functions.

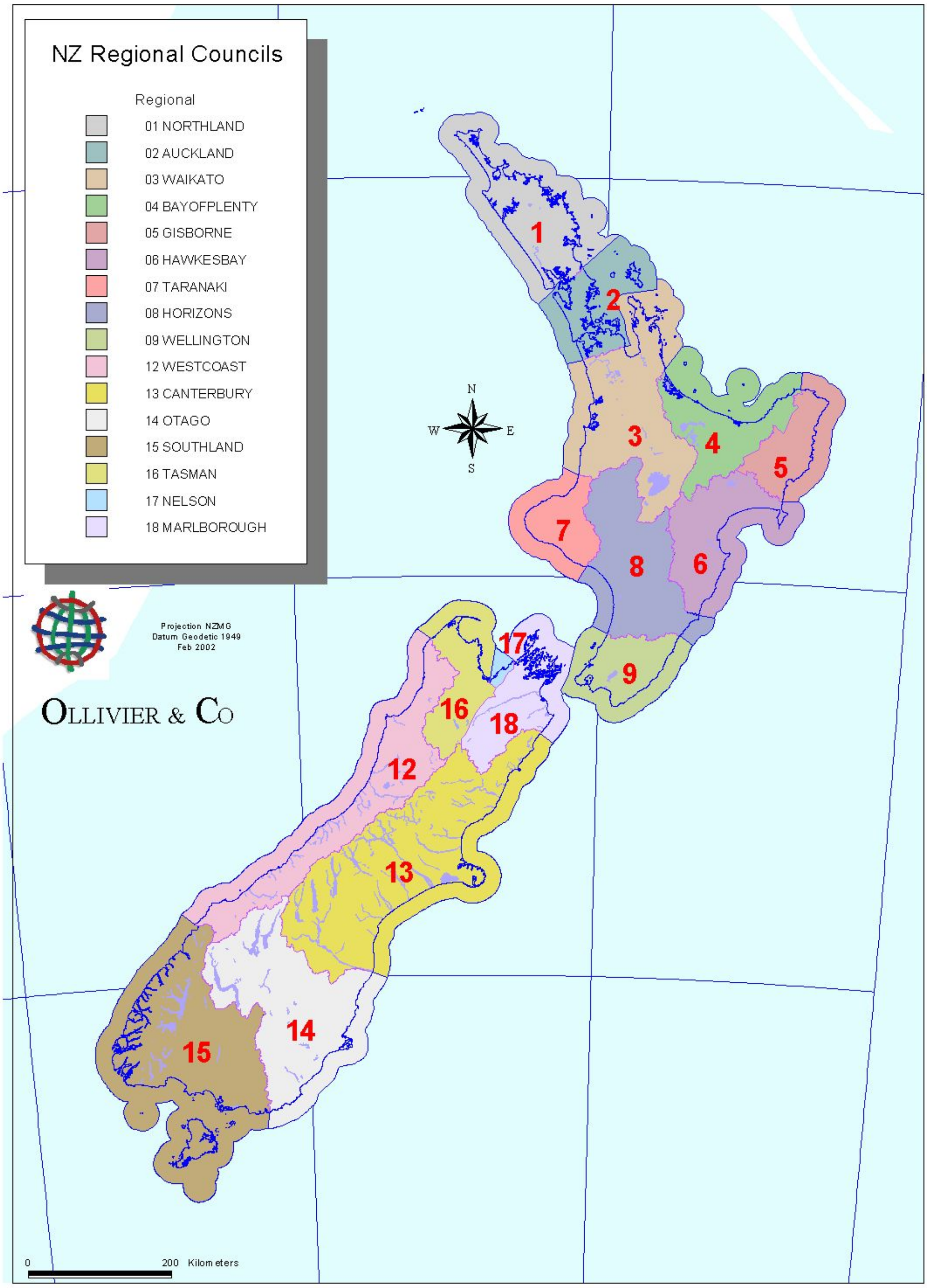
Will contribute to CDEMG group plan development, risk assessment, risk refinement, interdependence studies and vulnerability to volcanic hazard study.

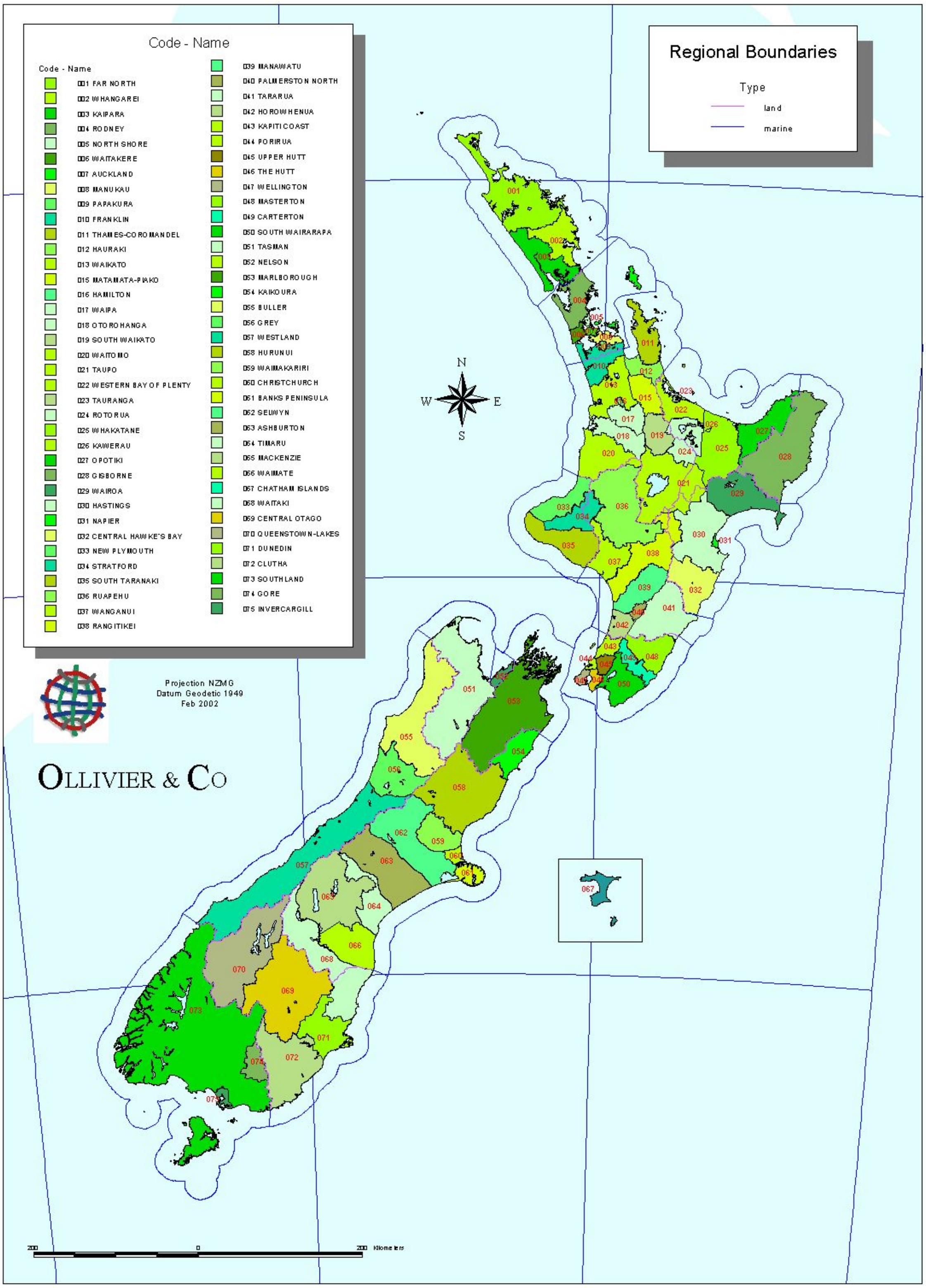
15. Overall, how would you rate the RCAs' ability to respond in a major natural hazard event? (Again if there are big differences in RCAs then please specify or show the range.)

Inadequate				Exceptional
1	2	3	4	5

Christchurch
Invercargill
West Coast (SI)
Manawatu-Wanganui
Hurunui
Waikato
Wellington
Nelson
Timaru
Rotorua
Dunedin
Hawkes Bay
Northland
Taranaki

Appendix B: Territorial and regional authorities in New Zealand




Code - Name
Code - Name
001 FAR NORTH
002 WHANGAREI
003 KAIPARA
004 RODNEY
005 NORTH SHORE
006 WAITAKERE
007 AUCKLAND
008 MANUKAU
009 PAPAKURA
010 FRANKLIN
011 THAMES-COROMANDEL
012 HAURAKI
013 WAIKATO
015 MATAMATA-PIAKO
016 HAMILTON
017 WAIPA
018 OTOROHANGA
019 SOUTH WAIKATO
020 WAITOMO
021 TAUPO
022 WESTERN BAY OF PLENTY
023 TAURANGA
024 ROTORUA
025 WHAKATANE
026 KAWERAU
027 OPOTIKI
028 GISBORNE
029 WAIROA
030 HASTINGS
031 NAPIER
032 CENTRAL HAWKE'S BAY
033 NEW PLYMOUTH
034 STRATFORD
035 SOUTH TARANAKI
036 RUAPEHU
037 WANGANUI
038 RANGITIKEI
039 MANAWATU
040 PALMERSTON NORTH
041 TARARUA
042 HOROWHENUA
043 KAPITI COAST
044 PORIRUA
045 UPPER HUTT
046 THE HUTT
047 WELLINGTON
048 MASTERTON
049 CARTERTON
050 SOUTH WAIRARAPA
051 TASMAN
052 NELSON
053 MARLBOROUGH
054 KAIKOURA
055 BULLER
056 GREY
057 WESTLAND
058 HURUNUI
059 WAIMAKARIRI
060 CHRISTCHURCH
061 BANKS PENINSULA
062 SELWYN
063 ASHBURTON
064 TIMARU
065 MACKENZIE
066 WAIMATE
067 CHATHAM ISLANDS
068 WAITAKI
069 CENTRAL OTAGO
070 QUEENSTOWN-LAKES
071 DUNEDIN
072 CLUTHA
073 SOUTHLAND
074 GORE
075 INVERCARGILL
Regional Boundaries
Type
land
marine
N
W
E
S
Projection NZMG
Datum Geodetic 1949
Feb 2002
OLLIVIER & CO
200
0
200 Kilometers