Auckland Regional Council

# Auckland Volcanic Risk Project: Stage 2

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# Auckland Volcanic Risk Project: Stage 2

**A report prepared for**

**AUCKLAND REGIONAL COUNCIL**

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## EXECUTIVE SUMMARY

In order to provide a basis for developing a framework for the comprehensive management of the wide range of risks associated with volcanic hazards, GNS has been working with the Auckland Regional Council towards a better understanding of the Auckland Volcanic Field and the hazards posed by a potential eruption. The first phase (completed in 1997) involved developing five eruption scenarios to illustrate what might happen in Auckland should an eruption occur, and a qualitative assessment of the effects of these scenarios on selected infrastructure, population and the environment generally. The second phase, presented in this report, was undertaken in 1998-1999, involved a more quantitative GIS risk assessment, including economic and social considerations of the eruption scenarios.

This study explores several factors that create vulnerability in the community (e.g., patterns of interaction between physical and social vulnerability, number and distribution of vulnerable groups) and finds that:

- Physical hazard characteristics can be used to anticipate the nature, intensity and duration of the social threat to communities, but more detailed vulnerability analysis is required to provide a comprehensive picture of social vulnerability
- Vulnerable groups are evenly distributed throughout the Region, creating a complex threat communication and mitigation environment
- To accommodate the diversity of vulnerable groups, communication and mitigation strategies must cater for the specific needs and resources of each group
- Destruction and disruption to the social and physical infrastructure caused by volcanic eruption will also affect the short and long-term economic status of the community.
- Economic vulnerability is influenced by the capability of local and central government agencies (e.g., need for income support, grants etc) and charitable organisations to manage these consequences, particularly in the light of the revenue implications of lost productivity over a period of months or even years.

The report concludes that accurate and comprehensive vulnerability analyses must identify the nature, number and distribution of vulnerable groups within the community. This information provides a basis for defining community needs, accommodating differences in needs and resources, and anticipating how community needs change over time. Once this has been done, analyses of interaction between hazard consequences and community vulnerability and functions can be used to develop appropriate communication and mitigation strategies. This study notes importance of developing liaison mechanisms between a range of organisations and community agencies representing groups identified as vulnerable. These liaison mechanisms can be used to develop training and educational programmes specific to the needs of each group and providing an input into the development of information management systems to support planning and response management.

# 1.0 INTRODUCTION

## 1.1 Background

The Auckland Regional Council has been working towards a better understanding of the Auckland Volcanic Field and the hazards posed by a potential eruption. The purpose of improving this understanding is to provide a basis for developing a framework for managing the wide range of risks associated with volcanic hazards. This risk management framework will allow the identification, assessment and treatment (or control) of physical, social, community and economic risks in a systematic and comprehensive manner (AS/NZS 4360: 1995). The past few years has seen work directed at developing five eruption scenarios (Johnston *et al.* 1997) (Figure 1) to illustrate what might happen in Auckland should an eruption occur, and a qualitative assessment of the effects of these scenarios on selected infrastructure, population and the environment generally.

The next phase (Stage 2) of this work involves a more quantitative risk assessment, including economic and social considerations of one or more of the eruption scenarios. Before undertaking the risk assessment, a review of the current information is required (identifying gaps), along with a framework for undertaking the risk assessment. The methodology developed as part of the proposed study is easily transferable to hazard and planning issues and can therefore be used in future projects, saving considerable development costs. The ultimate aim of this work is to gain a better understanding of the implications of a volcanic eruption at the Auckland Volcanic Field and how this information could be used to assist in planning and managing the response to an event.

## 1.2 Project Aim

The project has five specific aims:

- to develop a model which demonstrates the level of risk from interactions among the built, social and physical environments
- to develop a model which demonstrates the sensitivity in risk estimates due to variability in hazard and vulnerability parameters
- to develop a model which can be easily modified to suit a variety of hazards ("all-hazards" approach)
- to use the results to support and evaluate policy recommendations, including land use planning, preparedness and emergency response and recovery planning
- to develop a model which has potential to be used as an interactive education tool (e.g. on the internet)

## 1.3 Overview of this Report

This report commences with a discussion on the methodology adopted, limitations and problems encountered during the processing of the available data. Section 2 outlines the rationale for the selection of physical indices used to construct damage ratios. The next section (3) discusses economic factors that will impact on Auckland in the event of an eruption. Section 4 then proceeds to describe the risk status of the Auckland Region with respect to these criteria, based on a model linking physical, social and economic factors. Then, the sensitivity of the risk estimates derived from the above analysis is discussed in the context of variability in hazard and vulnerability parameters. Next, we consider how robust this model is with respect to its applicability within an all-hazards environment. Section 5 expands Scenario 4 (Central Business District) to illustrate the role and application of issues addressed in the report for volcanic hazard reduction and response management. In the final section the model is then used to frame the identification of issues that can be used to support and evaluate policy recommendations and the value of the model as an interactive educational tool.

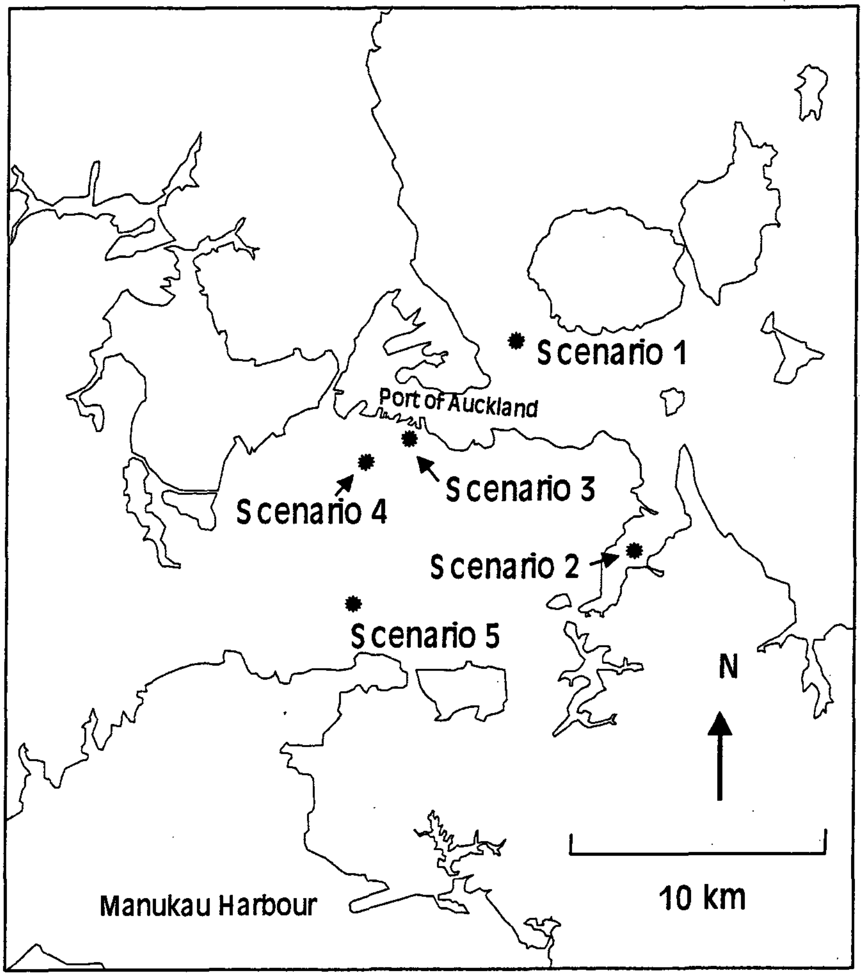


**Figure 1.** The five scenarios developed in the Phase 1 report (Johnston *et al.* 1997)

| | |
|---|---|
| Scenario 1 | An offshore, explosive eruption, involving seawater flashing to steam, centred in the Rangitoto channel, producing a smaller version of Rangitoto volcano. |
| Scenario 2 | A explosive eruption centred in the Tamaki Estuary, affecting residential and industrial areas. |
| Scenario 3 | A waterfront eruption centred in the railyards, affecting central business district, port, and residential areas. |
| Scenario 4 | A fire-fountaining eruption from a vent at the top (south) end of Queen Street, Auckland City, affecting the central business district (CBD). |
| Scenario 5 | A fire-fountaining eruption from a vent at the intersection of Mt Albert/Mt Eden roads, affecting residential and commercial areas. |

## 2.0 METHODOLOGY

### 2.1 Background

#### 2.1.1 Physical impacts

Considerable progress has been made over the past three decades in the understanding of the Auckland Volcanic Field. Eruption scenarios have been produced as a way of illustrating the types of impacts that might realistically be expected from a volcanic eruption (Johnston *et al.* 1997). Numerous types of hazards may result from a volcanic eruption, often simultaneously. The most likely hazards include pyroclastic falls, pyroclastic surges, lava extrusions, volcanic gases, volcanic earthquakes and atmospheric effects. Unfortunately there are very few quantitative measurements of the impacts of such hazards on communities and their 'lifelines'. Dowrick *et al.* (1990) have considered the damage cost on a number of eruption scenarios in Auckland using a simple damage ratio model. However, a number of their assumptions are questionable in light of recent detailed work and a more rigorous model is required.

#### 2.1.2 Economic Impacts

The economic impacts of an Auckland eruption will have short, medium and long term components. They will be caused by a combination of factors such as damage to structures (and their contents), utilities, transport systems (e.g. road, vehicles, airports), crops, forests; slowdowns or closure of business and industry; financial expenditure for mitigation measures, clean-up operations, repair and replacement of damaged utilities, buildings and contents; loss of personal, business and industry income; depletion of personal and business savings and/or capital; diversion of investment capital into recovery; increased tax burdens to finance response and recovery; alteration of land and property values etc. Amelioration of the medium and long term economic effects will depend on the response mechanism adopted.

At least one study has considered the economic consequences of an eruption in Auckland. Dowrick *et al.* (1990) assessed the potential losses that could be incurred by the Earthquake Commission. Savage (1997) presents a detailed review of the economic effects of a major earthquake in Wellington and concludes that the country is highly vulnerable to such events (and other economic shocks). Much of the methodology and conclusions developed by Savage are applicable to a study of an Auckland eruption. However, careful consideration of the differences between an earthquake and a volcanic event must be factored into any assessment. Among other things the duration and possible precursors of a volcanic eruption will make them distinct from earthquakes.

#### 2.1.3 Social impacts

Having constructed a hazard map of an affected area it will be possible to define risk profiles for given geographical areas and communities. The use of a GIS system can provide a valuable tool for assessing vulnerability from a variety of hazard maps. Using a range of data sets overlaid on

hazard maps, sub-area by sub-area can be examined to define levels of vulnerability as defined by a set of criteria. The physical risk profile can be supplemented with a social/community risk profile and economic risk profile. Risk status is not evenly distributed throughout a given area and differences are evident between communities and within communities and this will affect the distribution of risk to volcanic hazards. Consequently a detailed examination of social vulnerability factors is essential for planning, service delivery and resource identification and allocation.

## 2.2 Step 1 (Vulnerability Models) Workplan

The initial step of the project involves three primary tasks to define appropriate parameters for the risk assessment phase. This step will also focus on addressing potential limitations of the data sets

**Task 1** - Review the literature on physical vulnerability of structures, lifelines and people to Auckland's potential volcanic hazards and define appropriate parameters (damage ratios, casualty figures etc.) to be included in Step 2. Identify the limitations of current models and where it is possible to adapt them for use in this study.

**Task 2** - Review the literature on social vulnerability to natural hazards and define appropriate parameters from existing data sets to be included in Step 2.

**Task 3** - Review the literature on economic consequences of natural hazards at a macro and micro level. Define appropriate parameters from existing data sets to be included in Step 2.

## 2.3 Step 2 (Risk Assessment) Workplan

This step involves six tasks. Once Task 1 is complete Tasks 2-4 can proceed concurrently. At all stages the resolution of key data layers will need to be assessed to ensure that the limitations of these data sets do not affect the requirements of the project.

**Task 1** - Define the scenario(s) to be evaluated and plot hazard maps onto the GIS system.

**Task 2** - Create a physical risk profile with the GIS system using the parameters defined in Step 1. Undertake a sensitivity analysis for all parameters. Identify the physical parameters to be used in Task 5.

**Task 3** - Create a social risk profile with the GIS system using the parameters defined in step 1. Undertake sensitivity analysis for all parameters. Identify the social parameters to be used in Task 5.

**Task 4** - Create an economic risk profile with the GIS system using parameters defined in step 1. Undertake a sensitivity analysis for all parameters. Identify the economic parameters to be used in task 5.

**Task 5** - Combine the appropriate elements of physical, economic, social risk profiles and undertake sensitivity analysis.

**Task 6** - A discussion of the methodology, data, conclusions and limitations of the risk assessment will be prepared and submitted for review and comment. Following receipt of comments a final report will be prepared. This task will also include and identify areas where more detailed work (beyond this project) is required.

## 2.4 Methodology for Gathering Information

The spatial information requirements for the Auckland Volcanic Risks Assessment study were focussed on three areas:

- social and economic data from the Census 1996, extracted from SUPERMAP 3
- land value/capital value data from the then Valuation New Zealand (VNZ) Property database, October 1998 ( see note below )
- road network data from the LINZ Street Centrelines database which were buffered to produce the total road areas for ash fall calculations

The processing of the data was done in both ARC/INFO v7.2.1 and in ARCVIEW GIS v3.0. The polygons representing the extents of ash deposits for the Scenarios were derived from graphics files provided by GNS in Corel Draw format. These were transformed in ARC/INFO into GIS coverages and shapefiles as needed for ARCVIEW processing.

The buffer polygons, calculated at 5 kilometre raidii from the Scenario vents were created using the buffer command in ARC/INFO.

## 2.5 Problems Encountered

A number of problems were encountered during the second phase of the study and have limited the ultimate success of the risk assessment. Loss-estimates for each scenario have not been calculated due to problems encountered accessing valuation data.

Factors contributing to this include:

- the inconsistent link between VNZ-DCDB, particularly in the Central Business District
- the accuracy of the VNZ data itself

- the processing methodology (needs significant time to verify the information in the VNZ records)

Several issues arose during the data processing, some of which remain unresolved. These related to:

- the extraction of the Census data from Supermap by meshblock which is time consuming and places a heavy demand on the computer system.
- the insufficient data link between the land parcels database (DCDB) and the VNZ Property database. It was not possible to tag parcels accurately with the correct attribute values in many cases because the Terramatch equivalence table used had many missing links. This impacted on several fields of information that were requested including land values, capital values, building age and condition and building construction. No information for any of these values was provided. There is no simple resolution to this problem as the success of the link is determined by the fee paid to Terralink, who create the match. The evolution of Valuation New Zealand and the provision of property information by the Local Authorities may see an improvement in this situation in the near future.

The difficulty in getting property values associated with the DCDB (LINZ Digital Cadastral Database) has been further compounded by the devolution of *Valuation New Zealand*. The data is now held by the Territorial Local Authorities and their provision of this is still working through several initial supply problems.

There is still an issue with the Terramatch DCDB SUFI (a unique identifier number attached to each land parcel) and Property Assessment Number which *Quotable Value NZ* is still resolving. This is preventing a clear link between the two data sources and therefore holding back parcel based land and capital value information. A resolution is expected by September 2000.

## 2.6 Conclusion

As a result of a range of problems encountered the tasks in Step 2 of the work-plan have not been fully completed. However, progress has been made in developing the foundations for an integrated model of vulnerability to natural hazards, which can be built once additional information becomes available.

## 3.0 VULNERABILITY OF THE BUILT ENVIRONMENT

Numerous types of hazards would result from a volcanic eruption in the Auckland Volcanic Field. The most likely hazards include pyroclastic falls, pyroclastic surges, lava extrusions, volcanic gases, volcanic earthquakes and atmospheric effects. The cost of potential damage to structures from an eruption in the Auckland Volcanic Field are evaluated using only the three main hazards; pyroclastic surges, lava flows, and pyroclastic falls.

The damage ratio introduced in equation (1) is defined here for buildings and contents as,

$$D_r = \frac{\text{Cost of material damage}}{\text{Value of property at risk}} \quad (1)$$

### 3.1 Pyroclastic surges

The devastating impacts on structures of pyroclastic surges (and pyroclastic flows) has been well documented in historic eruptions like Vesuvius, A.D. 79 (Sigurdsson et al. 1985), Mount Pelée, 1902 (Boudon & LaJoie 1989), Mount Lamington, 1951 (Taylor 1958), Taal, 1965 (Moore et al. 1966). Pyroclastic flows and surges impart a lateral force to structures in the form of dynamic pressures (Valentine 1998), which depend on their bulk density (itself mainly a function of the particle concentration) and velocity. Valentine (1998) reviews the results of nuclear explosion tests undertaken on structures in the 1940's and 50's as a useful analog for the impacts of pyroclastic flows and surges, and presents probability of failure tables for a range of structures. However, observations of damage from historic volcanic eruptions show that the overpressures in the main body of these flows and surges are almost always sufficient to cause severe damage.

**Damage ratio:** A damage ratio of 1.0 is used for all areas within the surge zone. Although some historic surges show transitional zones between areas of complete destruction of buildings to areas of no damage, it is difficult to quantify this. Therefore, no transitional zone is used in this model. The social vulnerability attributable to physical loss and damage will be high in areas prone to pyroclastic surges (e.g. Scenarios 1, 2, and 3).

### 3.2 Lava flows

Geological evidence shows that basalt lava flows erupted from the Auckland Volcanic Field have included both block a'a lava and low viscosity pahoehoe flows which have been recorded at more than 10 km from the source vent. Both flow types will flow at right angles to the contour but only pahoehoe flows are sensitive to local topographic perturbations, especially in areas with slopes less than 5° (Trusdell 1995). Lava flows may slow on shallow slopes or accelerate on steeper ones. They seldom threaten human life because of their slow rate of movement.

However, if the steep fronts of flows become unstable they can collapse unexpectedly, causing small pyroclastic flows or new lobes of lava to develop (Blong 1984, Baxter 1990). Lava flows may cause extreme damage to buildings and other infrastructure, resulting from burial, ignition and/or excessive forces causing structural collapse. Blong (1984) describes a number of examples of damage from lava flows. Thick, slow moving a'a flows exert larger stresses on structures than more fluid pahoehoe flows, although in numerous cases flows have been diverted by resistant structures. The orientation of obstructing structures will influence the flow's behaviour, with structures perpendicular to flows having a higher risk of collapse. Inflation of pahoehoe flows may cause flows to overtop structures that initially halted their advance (Hon *et al.* 1994). The ignition of flammable materials is a common consequence of lava flow inundation. Some masonry buildings may survive, but most structures will be burnt out.

**Damage ratio:** Within areas affected by lava flows buildings are either destroyed or their use becomes untenable so that they are written off (i.e. a damage ratio of 1.0). Scenarios 3, 4, and 5 have been identified as vulnerable to lava flows. Lava flows will influence social vulnerability directly and indirectly. The sensitivity of this hazard effect to topography could extend social vulnerability if it results in an uneven distribution of impact within a given area or community.

### 3.3 Pyroclastic Falls

Volcanic ash damage to buildings and building services may happen in several different ways. Effects can be principally subdivided into (1) overloading roof strength causing collapse, and (2) less catastrophic building damage such as soiled interiors, interrupted services (electrical and mechanical) and damage to exterior materials (Johnston 1997, Johnston *et al.* 1997). These effects depend upon the thickness of ash, its mass and chemical reactivity, the building's roof form, construction and orientation, and the spacing of other buildings nearby. Determining the costs associated with less catastrophic building damage is hindered by the lack of data and is therefore restricted to estimations of clean-up costs.

**Ash loading:** Building failure or damage may result from ash loading on roofs and against walls or foundations (Blong 1981, 1984; Bitschene 1995; Blong & McKee 1995; Johnson & Threlfall 1985; Spence *et al.* 1996). The loading on a building is given by the equation:

$$L = \frac{dpg}{1000} \qquad (2)$$

where L is volcanic ash load (pressure in kPa)
d is ash depth (m)
p is ash density (kg $m^{-3}$)
and g is the gravitational acceleration (9.8 m $s^{-2}$).

Compaction increases the density of an ash cover but not its weight. Loading caused by ash depends on its thickness, density and whether it is dry or wet. Densities range from about 500 kg $m^{-3}$ for dry uncompacted ash to more than 2000 kg $m^{-3}$ for compacted very wet ash (Fig. 2).

Ash can influence vulnerability in several ways. While the most obvious is as a consequence of the damage it causes to buildings, the relationship between threat visibility and perceived vulnerability complicates this situation. For example, even if it does not pose a direct threat to the public, ash fall *per se* may be perceived as less threatening than invisible changes to water quality when ash enters the water system. Threat communication must address the needs that arise from the public perception of the threat, irrespective of the technical validity of their concerns.

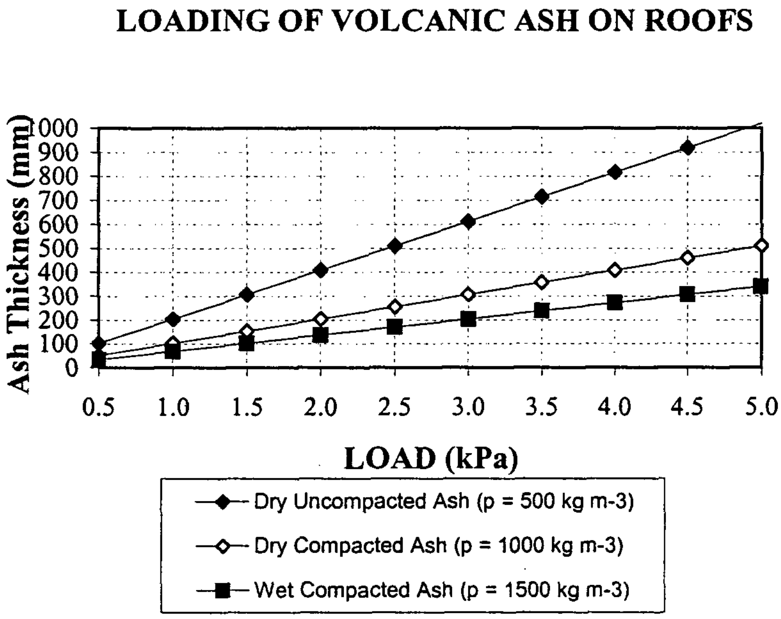


**Figure 2.** Loading of tephra on a roof for:
(a) dry uncompacted ash (p = 500 kg $m^{-3}$)
(c) wet uncompacted ash (p = 1000 kg $m^{-3}$)
(c) wet compacted ash (p = 1500 kg $m^{-3}$), 50% water saturation by volume

Blong (1984) gives several examples of roof collapse under ash falls. In most cases where ash fell to a thickness of <100 mm only a portion of buildings suffered roof collapse and/or damage whereas at >100 mm thickness more widespread collapses began to occur. Blong & McKee (1995) describe the damage to buildings during the 1994 Rabaul eruption.

> *"The damage sustained by roofs under the load of volcanic ash is undoubtedly a function of many key factors including ash thickness, ash bulk density, the moisture content of the ash, extent to which ash drifts (creating unbalanced dynamic loads), roof span and support systems, construction materials, roof slope and age and maintenance of the building."*

However, they do not assess the relative importance of these factors. A summary of their Rabaul observations is shown in Table 1.

**Table 1.** The effect of various ash loads on buildings in Rabaul (from Blong & McKee (1995))

| Ash thickness[1] | Estimated load[2] | Observed damage to roofs |
|---|---|---|
| <100 mm | 1.5-2.0 kPa | Roofs and guttering generally remained intact |
| <200 mm | 3.0-4.0 kPa | 80-90% of roofs remained intact with little apparent damage. Sagging or partial collapse occurred in some buildings |
| <300 mm | 4.5-6.0 kPa | More than 50 % of roofs **did not** collapse |
| 500-600 mm | 7.5-12.0 kPa | More than 50% of roofs collapsed. |
| >600 mm | 9.0-12.0 kPa | It is doubtful that buildings survived without significant damage even when the roof remained relatively intact |

[1] Ash fell wet; [2] Using equation 2 and assuming ash density of 1500 to 2000 kg $m^{-3}$

Rodolfo (1995) describes numerous roof collapses including warehouses and wide-span roofed buildings at a United States Navy base in the Philippines that received 150 mm of ash from the 1991 eruption of Pinatubo. A survey of building damage in the nearby town of Castillejos concluded that roofs failed because the ash load was greater than the vertical load-carrying capacity of their supporting structure (Spence *et al.*, 1996). Wide-span roofed buildings suffered more damage than short-span domestic scale construction.

Pitch angle is also a critical parameter in the vulnerability of roofs to collapse. Ash can obviously slide off steeply pitched roofs. Even moderate pitches can be less susceptible to collapse than flat ones. This has been frequently observed for ash-affected buildings. During heavy ash falls on the town of Vestmannaeyjar in Iceland in 1973, houses with roofs sloping at >20° suffered little damage from ash loading (Williams & Moore, 1973). Following the 1994 Rabaul eruption Blong and McKee (1995) concluded that under the same load:

> *"it seems clear that buildings with steep roofs survived better than those with gentle pitches ... a hotel where ash loads had been considered in the design of the steeply pitched roof, survived largely intact".*

Obstructions such as parapets, roof tanks or solar panels may cause accumulation of ash. In fact roof guttering is one of the most susceptible parts of a house to damage (Blong 1984, Blong & McKee 1995) and, especially after rain, the gutters may fill with ash and collapse. Roof pitch may have implications for social vulnerability directly (e.g. through direct damage) and indirectly (e.g. differences in distribution of damage as a consequence of differences in roof pitch).

**Damage Ratios:** Cost parameters are given below for two sources of costs arising from ash falls: (1) damage costs for buildings (excluding underground services); (2) clean up. In the absence of better data, buildings are divided into two somewhat simplistic classes, those with strong (i.e. concrete slab) roofs, and those with lightweight roofs (non-concrete slab).

The damage ratios for lightweight roofs (Table 2) are based largely on experience in Rabaul as reported by Blong & McKee (1995), while those for concrete roofs (Table 3) are based on gravity collapse loads derived from a simple interpretation of New Zealand design codes. The damage ratios are based roughly on:

- proportion of building damaged at and near roof
- height of buildings (clean-up costs increase with height)
- some (small) ground floor damage from mud flows
- shop verandah damage

The cost of clean up of ash will vary greatly depending on the exact circumstances, e.g. ease of access, haulage distance, and dumping charges. Charges of $10 - $30 per cubic metre of ash may be representative. This implies costs of $100 - $300 per mm thickness per hectare in area.

Not all ash will necessarily be removed mechanically. Some very thin or very thick layers are likely to be left in place, as happened in the Philippines after the 1991 Pinatubo eruption.

The clean-up operation could be very large. A loader feeding a fleet of six large trucks (10 tonne) would dispose of about 3000 $m^3$ per day. A related major question is the site of ash disposal.

Clean-up costs for roads, sewers and stormwater systems can be estimated from data collected from four historic eruptions and is summarized in figure 3. A linear regression has been applied to the data and used to estimate costs in this model.

**Table 2.** Cost parameters for volcanic ash falls on buildings with lightweight roofs [(1)]

| Ash thickness (mm) | Approx. loading (kPa) | Condition of property | Mean damage ratio | Cost per hectare per mm thickness |
|---|---|---|---|---|
| < 1 | * | No costs | 0 | 0 |
| > 1 | * | Clean-up required | * | $100 - $300 |
| 200 | 1 - 3 | 20% of buildings collapse | 0.3 | * |
| 400 | 2 - 6 | 40% of buildings collapse | 0.6 | * |
| 500 | 2.5 - 7.5 | 80% of buildings collapse | 0.8 | * |
| 600 | 3 - 9 | 100% of buildings collapse | 1.0 | * |

Notes: (1) Buildings of 1-2 storeys with lightweight roofs, including houses and non-domestic buildings.
* Not applicable

**Table 3.** Cost parameter for volcanic ash falls on buildings with reinforced concrete slab roofs

| Ash thickness (mm) | Approx. loading (kPa) | Condition of property | No. of storeys | Mean damage ratio | Cost per hectare per mm thickness |
|---|---|---|---|---|---|
| < 1 | * | No costs | * | 0 | 0 |
| > 1 | * | Clean-up required | * | * | $100 - $300 |
| 1000 | 5 - 15 | 10% of roofs collapse | 3 | 0.03 | * |
| | | | 10 | 0.01 | * |
| 1500 | 8 - 22 | 80% of roof collapse | 3 | 0.3 | * |
| | | | 10 | 0.1 | * |
| 2000 | 10 - 30 | 100% of roofs collapse | 3 | 0.4 | * |
| | | | 10 | 0.2 | * |

Notes: * Not applicable

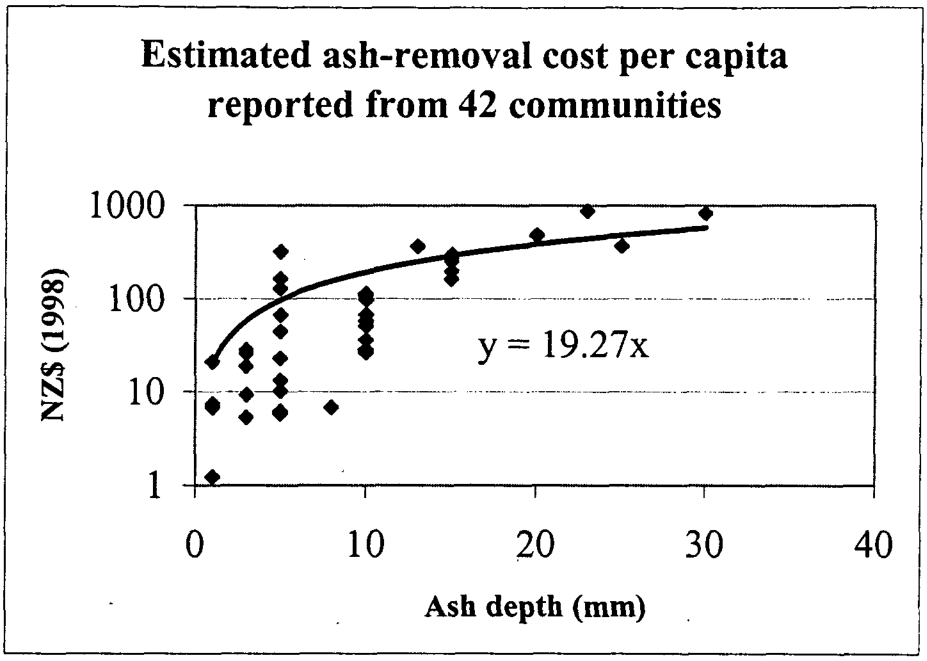


**Figure 3.** Estimated ash-removal cost per capita versus ash depth reported from 42 communities (includes removal from road and sewage/stormwater systems). The 1980 ash clean up in Yakima and other Washington communities resulted from the 18 May 1980 eruption of Mount St Helens (reported by Warrick et al. 1981). The 1992 Anchorage ash clean-up was a consequence of the 18 August 1992 eruption of Mt Spurr (Johnston 1997) and the 1996 ash clean-up in Rotorua was a result of the 17 June 1996 eruption of Ruapehu (Johnston 1997). The costs have been adjusted to 1998 values by converting to $NZ and using the New Zealand consumer price index.

## 4.0 ECONOMIC ISSUES AND PARAMETERS

This section reviews the literature on the economic consequences of natural hazards at a macro and micro level and defines or identifies appropriate parameters from existing data sets to be included in the risk analysis.

The economic impacts of earthquakes affecting Wellington has been studied in detail (Savage 1997) and this study provides a sound theoretical basis for any economic analysis of a natural hazard event. While volcanic events have particular characteristics that are different from earthquakes (discussed below), the general issues are similar. The key differentiating characteristic of natural hazards, that significantly affects the magnitude of the consequence aspect of the risk, is the amount of warning that a community is likely to receive.

A brief survey of summary literature has shown that there has been a reasonable amount of work reporting on the economic impacts of flooding. One reason for this is that floods are fairly common events in many parts of the world and there is considerable data available. Economic models have been developed, particularly in the United States, to analyse the effects of flooding. These models are often used as predictive models to assist in evaluating the viability of a water management or irrigation scheme.

Similarly, there have been a number of economic studies of the impacts of earthquakes undertaken. Most of these have been post-event studies that have evaluated the cost of cleanup and recovery.

The report by Savage (1997) reviews the literature with respect to the economic effects of major earthquakes, identifies a series of issues, develops an economic framework based on the linkages between these issues, and assesses the economic effects of a major earthquake using this framework. The framework links the size and nature of the destructive effects, the vulnerability (initial social, physical and economic conditions), and the responsiveness of individuals, institutions and markets to short term and long term impacts, through feedback effects. He notes that the economic literature provides surprisingly little guidance on the economic effects of earthquakes, and that most of what is available concentrates on microeconomic impacts focusing on the immediate cost. From a macroeconomic perspective, there appear to be two opposing views. The first is attributed to a book by Albala-Bertrand (1993) entitled 'Political Economy of Large Natural Disasters' where 28 disasters between 1960 and 1979 are analysed.

This view suggests that:

- disasters have localised impacts

- unless particular industries are only located in the affected area the economy-wide effects on the sector are limited
- many potential negative effects such as shortages and resulting price pressures do not actually occur
- the scale of losses tends to be overestimated

This view runs counter to economic predictions and is in contrast to other studies of individual events where losses have been significant.

Savage (1997) identified a series of issues that may help to explain the divergence in opinion:

- wealth or stock effects
- debt effects (funding of reconstruction)
- hysteresis and feedback effects (ratchet)
- initial conditions (state of the economy prior to the shock)
- country type (characteristics)
- business confidence effects
- economic management
- regional vs economy wide effects
- distributional effects
- measurement problems

These issues have been used to develop an economic framework to analyse the economic effects of a major earthquake. In addition, a number of scenarios are analysed using economic models. The results of the Savage (1997) study have some applicability to the effects of volcanic events, although there are some important characteristics of volcanic events that differentiate the economic effects from those resulting from earthquakes. For example, an earthquake is an unpredicted event that lasts for seconds rather than minutes, while there may be considerable warning of the general location of a volcanic eruption, and it may last for weeks or even years.

Tierney (1997) undertook an interesting study after the Northridge earthquake in California, looking at business preparedness and recovery. Some of the relevant general findings were that:

- businesses, especially small ones, do not prepare for disasters
- the larger the business the more likely it to take disaster planning measures
- businesses are vulnerable to off-site impacts such as loss of utilities, and will have difficulty functioning even if not directly affected through staff not being able to get to work, and materials not being delivered
- business interruption insurance was not used because of high deductibles or because they were not eligible to use it because of the wording of the policy

### 4.1 Impacts of Volcanic Activity

The impacts most likely to result from a major volcanic eruption in the Auckland metropolitan area can be divided into groups according to several classifications, including direct and indirect effects, and short term and long term effects.

From an economic perspective the direct costs of a major natural hazard event are linked to the loss of:

**1) Direct costs**

- natural capital (natural resources and landscape features such as natural harbours)
- business sector capital (commercial and industrial buildings, plant and material)
- lifelines
- public sector capital stock (schools, hospitals, government agency plant and equipment)
- housing stock

Cleanup costs are also direct costs, but may be incorporated in the previous list. In addition, a further direct cost is the loss of human capital or the talents and knowledge of individuals.

Each of these contributes to GDP either directly or indirectly. Economic costs have two dimensions (value of lost production, reduction in wealth). In principle, both losses can be insured against through business interruption insurance or standard insurance[1]. In practice, a very major event such as a volcanic eruption in downtown Auckland would have such a high damage cost that unless insurance were well spread and much of it carried offshore the impacts on the local insurance industry could be crippling. Individual businesses and organisations may adopt prudent financial risk management acknowledging these types of effects, but they are unlikely to be aware of the broader perspective. It becomes the responsibility of the insurance industry to manage the cumulative risk.

**2) Indirect costs**

Indirect costs likely to result from volcanic activity include loss of business activity, loss of tourism, injuries resulting from cleanup activities and other less measurable impacts such as increased doctor and hospital visits through anxiety, either during or prior to an eruption.

Non-economic losses (socio-economic losses) include inconvenience, lost leisure, pain and suffering, loss of personal assets, and loss of historical/cultural assets. Non market valuation techniques could be used to measure the losses associated with these assets.

[1] Note that replacement value is not the same as insured value, not all losses are permanent, and the economic interest is in lost 'value added' not gross output..

## 4.2 Characteristics of Volcanic Eruptions

Volcanic eruptions are powerful and dramatic agents of change. Because of their destructive nature and the continuing unrest and disruption, people living near volcanoes may be forced to move from the area for significant lengths of time, or even permanently. While the most destruction will be in the immediate vicinity of the volcano[2], associated impacts can affect many people living further away. For example, ash may prevent planes flying in the area, and water may be contaminated.

All natural hazard events can be characterised in time and space. Temporal characteristics are warning time, and duration. Spatial characteristics are linked to the size of the event and the distribution of impact.

One of the important characteristics of volcanoes is that in most cases there is a significant amount of lead-time or warning. This is in contrast to earthquakes where there is seldom any warning.

In the scenarios posed in Johnston *et al* (1997), a build-up time of 25 days was assumed. For Auckland, it is recognised that the warning may not be specific: it is likely that the exact location of the eruption will not be known until a very short time before the event. However, it is assumed that the warning time will be adequate to ensure evacuation of all people living and working in the area.

The duration of volcanic activity is more difficult to address. Obviously there will be considerable disruption of economic and business activity during the warning period and high anxiety will be generated. Many residents may choose to leave as a precaution. Businesses may have to make decisions about whether to relocate in the short term.

Following a warning period of indeterminate duration, an eruption may occur which may last from days, to weeks or months. An initial eruption may be followed by a period of smaller eruptions. Cleanup may need to be an on-going activity.

Once it has been determined that the major volcanic activity has ceased, the time taken for cleanup and return to normal activities will depend on the size and location of the eruption. An eruption in the strait between Rangitoto and the main harbour area might cause less destruction of buildings and infrastructure than an eruption in Queen Street, but if the port were damaged and the sea floor rose, the port area might become unusable. All shipping would need to be diverted and the effect on commercial activity would be immense.

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[2] Estimate in this case is 1-3 km.

The cost and timing of recovery will also depend on whether it is considered possible to rebuild and restore services, or whether the damage is so severe that it is decided to abandon some areas.

## 4.3 Differences between Volcanic Eruptions and other Natural Hazards

Significant differences between earthquakes and volcanic eruptions that will impact on economic assessment:

- volcanic eruptions usually have some warning even if the exact vent location is uncertain. This causes considerable uncertainty and on-going stress.
- earthquakes do not give warning. Once the shock is over cleanup can begin immediately.
- volcanic eruptions can last for long periods of time causing continuing damage and disruption (for example, the impacts of the eruption of Mt Pinatubo in the Philippines have lasted from 1991 to the present day).
- earthquakes last for a few seconds or minutes. Aftershocks may continue for several days causing considerable mental anguish, but they are always less severe than the main shock.

Jackson (1981) notes that one of the characteristics of earthquakes is that they are intangible, and there is not usually any evidence of them in the environment. Whereas floods are associated with rivers, in most cases earthquake faults are not visible to the average person. Most volcanoes are visible, and an ever present reminder. On the other hand in an area such as Auckland where an eruption has not occurred in living memory there is a tendency to discount the hazard.

## 4.4 Economic Parameters

A key objective of this project is to establish a risk management plan for Auckland for volcanic risks. One of the first steps in this process is to establish the risk management context for the activity, to set the criteria for evaluating risks, and to identify stakeholders and interested parties.

To do this, it is necessary to specify a set of parameters that may provide information about the consequences of a volcanic eruption. This section of the study is concentrating on socio-economic factors, and therefore the parameters that are identified will be linked to social and economic conditions.

The parameters listed below are an initial indicative list that can be refined as the project progresses. They provide base information about the social and economic conditions that pertain to particular areas. One of the intentions is to use GIS to develop scenarios and models, therefore the parameters have been selected with this in mind. No attempt has been

made to identify cause-effect relationships, which may reduce the number of parameters required.

Some of the parameters will be able to be measured quantitatively, while others will be qualitative.

**Table 4.** The availability of information for various parameters.

| **Parameters** (based on grid blocks) | **Availability of information** **A easy** **B moderate** **C difficult** | |
|---|---|---|
| Replacement value of domestic buildings | B | |
| Replacement value of commercial buildings | B | |
| Replacement value of government and agency buildings[3] | B | |
| Number of inhabitants (by demographic breakdowns) | A | |
| Number of residents with employment | A | |
| Number of daytime workers | A | |
| Number of people employed in the area | A | |
| Number of small businesses | A | |
| Ratio of land area residential/other | A | |
| Access routes (lifeline elements and re-routing options) | B | |
| Availability of empty premises within easy range | B/C | |
| Cost of temporary relocation (range of time periods e.g. 4 weeks, 12 weeks, 26 weeks) | B/C | ↕ Distance related |
| Cost of permanent relocation | B | |
| Availability of (heavy) equipment & nearest depot | A | |
| Mobility of residents (socio-economic factors) | B | |

Some parameters will need to be looked at in a city-wide basis. For example, impacts on engineering lifelines, major structures, and features such as the Port of Auckland and the International Airport. Factors that need to be considered in the identification or development of parameters to be incorporated into the risk assessment are related to the risk posed by the volcanic hazard. Therefore, aspects of likelihood and magnitude of consequence need to be considered. The parameters specified here are all measures of magnitude of impact. The *likelihood* of impact will be a combination of the probability of volcanic activity combined

[3] For these first three categories an indication of type of insurance cover, insured value, and 'location' of insurance is also important, but likely to be more difficult to determine.

with the probability of that element (parameter) being affected by the eruption. The judgement of whether or not a parameter is relevant thus links back on the one hand to how likely it is that that element will be affected, and also, whether or not that parameter is able to be measured either quantitatively or qualitatively, directly or indirectly.

### 4.5 Estimating Economic Cost of Damage and Recovery

An attempt has been made to estimate the magnitude of the costs/losses resulting from each eruption scenario. Two costs are assessed; firstly, damage to buildings and land, and secondly ash clean-up costs. The limitations and assumptions for each approach are discussed in turn.

***Damage to land and property***

For each scenario, losses resulting from damage to land and property can be calculated using valuation data multiplied by damage ratios for a range of hazard types (outlined earlier and summarised in Table 5). However, due to difficulties in using the valuation data from the Valuation New Zealand (VNZ) database it has not been possible to calculate the total losses to land and building at this stage, thus the model provides the framework for future loss calculations once these problems have been solved. An explanation of the difficulties that arose are described in section 2.3.

**Table 5.** Summary of damage ratios used for assessing land and property losses.

| Hazard type | Land value | Damage ratio | Building value | Damage ratio | Note |
|---|---|---|---|---|---|
| Lava flows | * | 1.0 | * | 1.0 | Model assumes total loss of land value |
| Pyroclastic surges | n/a | n/a | * | 1.0 | Model assumes no land value loss |
| Ash falls | n/a | n/a | * | (see table 2 and 3) | Model assumes no land value loss |
| Ballistics | n/a | n/a | * | 0.2 | Model assumes no land value loss |

* = values used in the model

***Clean-up cost***

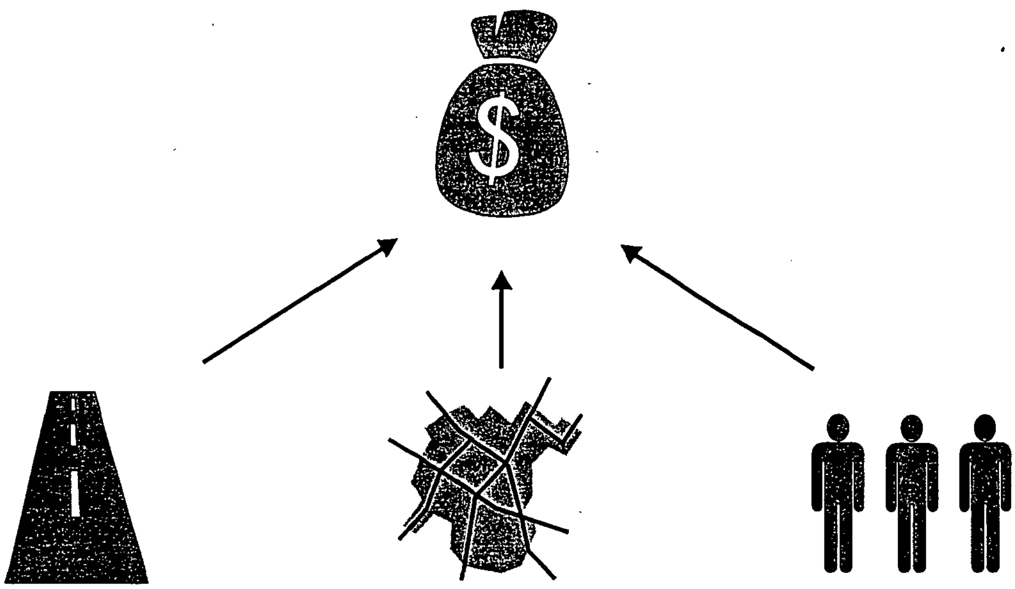
To assess potential clean-up costs three approaches are considered:

A) removal of ash from roads only.

B) removal of ash from the total urban area.

C) estimated clean-up costs per capita based on experience from historic eruptions.

Estimated clean-up costs associated with ash removal



A: Clearance from roads only

B: Clearance from entire metropolitan area

C: Clearance based on metropolitan population

**Figure 4.** Estimated clean-up costs associated with ash removal

***A: Removal of ash from roads only***

Table 6 contains the calculated costs for ash removal from roads within the Auckland metropolitan limits, for each eruption scenario. Total ash volumes are calculated in cubic metres for metropolitan roads by summing the ash volume within each isopach interval, as calculated according to:

- the length of road (derived from the 1998 Road Centrelines for the region supplied through Terralink NZ Ltd from the LINZ database)
- an average road width of 20m (total width of paved surface including footpaths)
- taking the median ash depth (e.g. 1-5 mm as 3 mm, 5-10 mm as 7.5 mm, 10-50 mm as 30 mm, and > 50 mm as 50 mm) within each isopach interval

These volumes were then multiplied by an estimated cost per unit volume for ash clearance and disposal of either $\$10/m^3$ or $\$30/m^3$ (Table 2 and 3) to obtain the figures presented in Table 6.

***B: Removal of ash from the total urban area***

Table 7 contains the calculated cost for the removal of ash from all land within the Auckland metropolitan limits, for each eruption scenario. Total ash volumes are calculated in cubic metres for the metropolitan area by summing the ash volume within each isopach interval, as calculated according to:

- the area within each isopach interval in hectares (derived from a coastline combined with the Metropolitan Limits Line, 1996). The potential digitising error of 5 m in this analysis is negligible
- taking the median ash depth (e.g. 1-5mm as 3 mm, 5-10 mm as 7.5 mm, 10-50 mm as 30 mm, and > 50 mm as 50 mm) within each isopach interval

These volumes were then multiplied by an estimated cost per unit volume for ash clearance and disposal of either $\$10/m^3$ or $\$30/m^3$ to obtain the figures presented in Table 8.

***C: From per-capita clean-up costs derived from historic eruptions***

Table 8 contains estimates of ash clean-up costs for Auckland eruption scenarios using estimates of per-capita clean-up costs obtained from historic eruptions that affected urban areas (summarised in Figure 3). A linear regression was applied to the data and used to estimate per-capita clean-up costs in this model. Total clean up costs for each scenario were calculated by summing the product of the per-capita cost per unit ash thickness and the population within each isopach interval, according to:

- population within each isopach interval (from 1996 census)
- clean-up cost per-capita for the particular ash thickness within the interval (derived from Figure 3)

**Table 6.** Cost of ash removal from all roads within the metropolitan limits

| Scenario 1<br>Ash depth | Volume ($m^3$) | \$10/$m^3$ | \$30/$m^3$ |
|---|---|---|---|
| 50mm+ | 52080 | $521,000 | $1,562,000 |
| 10-50mm | 497043 | $4,970,000 | $14,911,000 |
| 5-10mm | 75231 | $752,000 | $2,257,000 |
| 1-5mm | 91801 | $918,000 | $2,754,000 |
| | **Total** | $7,161,000 | $21,484,000 |
| **Scenario 2<br>Ash depth** | **Volume ($m^3$)** | **\$10/$m^3$** | **\$30/$m^3$** |
| 50mm+ | 115778 | $1,158,000 | $3,473,000 |
| 10-50mm | 202021 | $2,020,000 | $6,061,000 |
| 5-10mm | 44175 | $442,000 | $1,325,000 |
| 1-5mm | 27601 | $276,000 | $828,000 |
| | **Total** | $3,896,000 | $11,687,000 |
| **Scenario 3<br>Ash depth** | **Volume ($m^3$)** | **\$10/$m^3$** | **\$30/$m^3$** |
| 50mm+ | 259270 | $2,593,000 | $7,778,000 |
| 10-50mm | 546651 | $5,467,000 | $16,400,000 |
| 5-10mm | 60484 | $605,000 | $1,815,000 |
| 1-5mm | 49392 | $494,000 | $1,482,000 |
| | **Total** | $9,159,000 | $27,475,000 |
| **Scenario 4<br>Ash depth** | **Volume ($m^3$)** | **\$10/$m^3$** | **\$30/$m^3$** |
| 50mm+ | 330030 | $3,300,000 | $9,901,000 |
| 10-50mm | 408124 | $4,081,000 | $12,244,000 |
| 5-10mm | 72461 | $725,000 | $2,174,000 |
| 1-5mm | 58268 | $583,000 | $1,748,000 |
| | **Total** | $8,689,000 | $26,067,000 |
| **Scenario 5<br>Ash depth** | **Volume ($m^3$)** | **\$10/$m^3$** | **\$30/$m^3$** |
| 50mm+ | 309906 | $3,099,000 | $9,297,000 |
| 10-50mm | 493887 | $4,939,000 | $14,817,000 |
| 5-10mm | 89406 | $894,000 | $2,682,000 |
| 1-5mm | 83926 | $839,000 | $2,518,000 |
| | **Total** | $9,771,000 | $29,314,000 |

**Table 7.** Cost of ash removal from all land within the metropolitan limits

| Scenario 1 | | | |
|---|---|---|---|
| **Ash Depth** | **Hectares** | **$100/mm/ha** | **$300/mm/ha** |
| 50mm+ | 590 | $2,950,000 | $8,850,000 |
| 10-50mm | 10294 | $30,882,000 | $92,646,000 |
| 5-10mm | 6170 | $4,628,000 | $13,883,000 |
| 1-5mm | 14957 | $4,487,000 | $13,461,000 |
| | **Total** | $42,947,000 | $128,840,000 |
| **Scenario 2** | | | |
| **Ash Depth** | **Hectares** | **$100/mm/ha** | **$300/mm/ha** |
| 50mm+ | 1511 | $7,555,000 | $22,665,000 |
| 10-50mm | 3582 | $10,746,000 | $32,238,000 |
| 5-10mm | 3558 | $2,669,000 | $8,006,000 |
| 1-5mm | 6093 | $1,828,000 | $5,484,000 |
| | **Total** | $22,798,000 | $68,393,000 |
| **Scenario 3** | | | |
| **Ash Depth** | **Hectares** | **$100/mm/ha** | **$300/mm/ha** |
| 50mm+ | 3038 | $15,190,000 | $45,570,000 |
| 10-50mm | 10801 | $32,403,000 | $97,209,000 |
| 5-10mm | 5366 | $4,025,000 | $12,074,000 |
| 1-5mm | 8979 | $2,694,000 | $8,081,000 |
| | **Total** | $54,312,000 | $162,934,000 |
| **Scenario 4** | | | |
| **Ash Depth** | **Hectares** | **$100/mm/ha** | **$300/mm/ha** |
| 50mm+ | 3051 | $15,255,000 | $45,765,000 |
| 10-50mm | 8860 | $26,580,000 | $79,740,000 |
| 5-10mm | 6032 | $4,524,000 | $13,572,000 |
| 1-5mm | 14201 | $4,260,000 | $12,781,000 |
| | **Total** | $50,619,000 | $151,858,000 |
| **Scenario 5** | | | |
| **Ash Depth** | **Hectares** | **$100/mm/ha** | **$300/mm/ha** |
| 50mm+ | 3767 | $18,835,000 | $56,505,000 |
| 10-50mm | 10984 | $32,952,000 | $98,856,000 |
| 5-10mm | 7836 | $5,877,000 | $17,631,000 |
| 1-5mm | 9576 | $2,873,000 | $8,618,000 |
| | **Total** | $60,537,000 | $181,610,000 |

**Table 8.** Ash clean-up costs for eruption scenarios using estimates from past eruptions

| Scenario 1 | | | |
|---|---|---|---|
| **Ash Depth** | **Number of people** | **Cost per person** | **Area cost** |
| 50mm+ | 308877 | $58 | $17,856,000 |
| 10-50mm | 103485 | $145 | $14,956,000 |
| 5-10mm | 20876 | $578 | $12,068,000 |
| 1-5mm | 13941 | $964 | $13,432,000 |
| | | **Total cost** | $58,312,000 |
| **Scenario 2** | | | |
| **Ash Depth** | **Number of people** | **Cost per person** | **Area cost** |
| 50mm+ | 92229 | $58 | $5,332,000 |
| 10-50mm | 53301 | $145 | $7,703,000 |
| 5-10mm | 71790 | $578 | $41,502,000 |
| 1-5mm | 33171 | $964 | $31,960,000 |
| | | **Total cost** | $86,497,000 |
| **Scenario 3** | | | |
| **Ash Depth** | **Number of people** | **Cost per person** | **Area cost** |
| 50mm+ | 175965 | $58 | $10,173,000 |
| 10-50mm | 88428 | $145 | $12,780,000 |
| 5-10mm | 23168 | $578 | $13,393,000 |
| 1-5mm | 59694 | $964 | $57,515,000 |
| | | **Total cost** | $93,861,000 |
| **Scenario 4** | | | |
| **Ash Depth** | **Number of people** | **Cost per person** | **Area cost** |
| 50mm+ | 224013 | $58 | $12,950,000 |
| 10-50mm | 140634 | $145 | $20,325,000 |
| 5-10mm | 191334 | $578 | $110,610,000 |
| 1-5mm | 64791 | $964 | $62,426,000 |
| | | **Total cost** | $206,311,000 |
| **Scenario 5** | | | |
| **Ash Depth** | **Number of people** | **Cost per person** | **Area cost** |
| 50mm+ | 187155 | $58 | $10,819,000 |
| 10-50mm | 150216 | $145 | $21,710,000 |
| 5-10mm | 222039 | $578 | $128,361,000 |
| 1-5mm | 85650 | $964 | $82,524,000 |
| | | **Total cost** | $243,414,000 |

### 4.6 Summary and Conclusions

Major volcanic eruptions are comparatively rare events, and there is limited data available on their economic impacts. Most of the information on past eruptions is mainly concerned with the type of eruption and the number of people killed. While some historic eruptions have occurred near major towns and centres of population, there is little evidence readily available of impacts on business activity.

The expectation for the Auckland Volcanic Field is that there will be reasonable warning of an eruption, although the specific locations would not be able to be pinpointed until quite close to the time of eruption. Given current knowledge of the type of volcanic eruption, an estimate of the size of the area likely to be affected could be made, and all potentially affected people could be relocated.

Therefore, the main direct impacts of an Auckland volcanic eruption are expected to be on property and the environment, with considerable destruction of property expected, and high costs of cleanup both for removal of damaged property and removal of ash. While property damage is likely to limited to a comparatively small area, ash fall will affect a large area, and may be an on-going process with continuing eruptions.

There will be direct impacts on people who may choose to relocate either temporarily or permanently and the receiving communities, further direct effects on employment, and indirect effects resulting from stress and loss of opportunity.

Effects on businesses will also be direct (buildings and property) and indirect (loss of business, cost of relocation etc).

The dollar value of land and properties damaged or destroyed by an eruption scenario can be estimated by multiplying their values by damage ratios for the respective hazard types. However, valuation data is still required in order to complete this task.

Three methods of estimating potential clean-up costs have been used:
A) removal of ash from roads only;
B) removal of ash from the total urban area; and
C) estimated from per-capita clean-up costs derived from historic eruptions.

Techniques A and B are just different ways of calculating the total volume of ash that should be removed. The lowest estimates are derived when only the costs of ash removal from roads are considered. However, historic examples of ash removal from urban areas show that

recovery costs are associated not only from cleaning roads, but also from cleaning stormwater and sewage systems, other paved surfaces, and buildings.

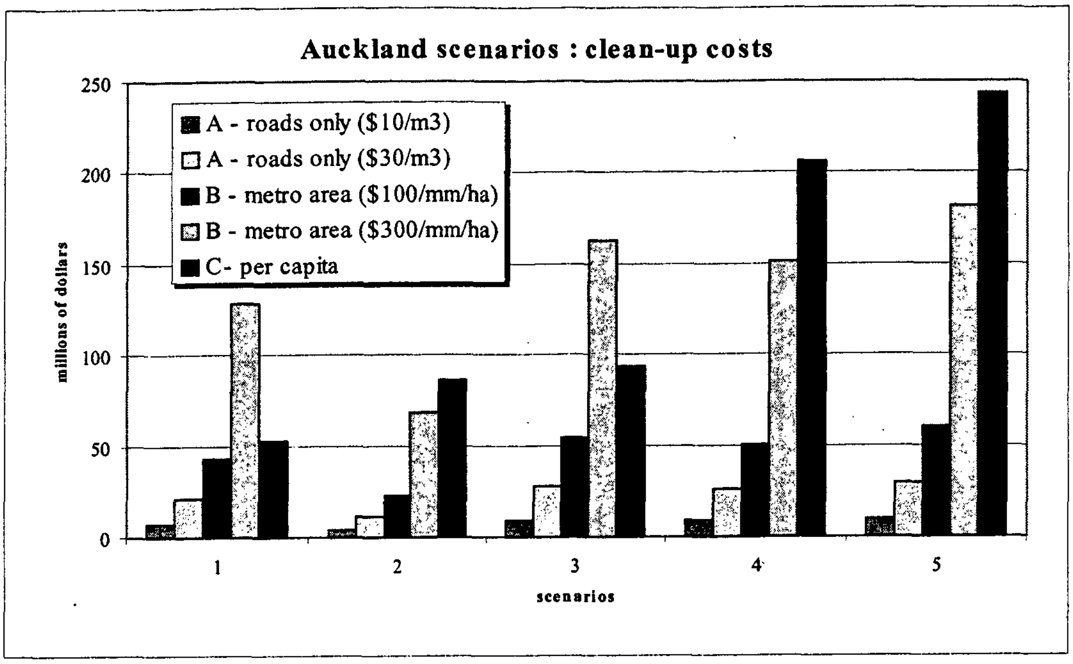



**Figure 5.** Summary of estimated clean-up costs using three methods

To attempt to gauge the cost of such operations, estimates of the cost of removing ash from the entire urban area have been calculated using a figure of $100 to $300 per mm of ash per hectare (corresponding to $10/m^3$ and $30/m^3$). This is a simplistic approach as it does not take into account the land-use or level of development within a given area. A third approach taken has been to use estimates of ash removal costs from urban areas during historic eruptions. These figures have been converted to a per-capita cost and applied to the Auckland scenarios. In three out of the five scenarios, these per-capita based figures are greater than the cost of removing ash from the entire land area (Figure 4). This highlights the sensitivity of per-capita methods to population density, something that is not a problem with land area approaches. However, both methods illustrate the high costs that urban areas will face in ash removal operations. It is likely that the true cost of ash removal will be tens to hundreds of millions of dollars, for any given scenario.

## 4.7 Discussion

### 4.7.1 Factors determining levels of physical impact

Analysis of loss estimations for the anticipated type of volcanic activity shows that the level of physical impacts is primarily determined by the location of the vent, but the clean-up costs are a product of the distribution of tephra. This is controlled principally by weather

conditions, such as wind speed and direction at the time of the eruption. The duration of the eruption will also be a significant factor, since the longer that an eruption persists, the more likely it is that shifting wind patterns will cause multiple sectors around the vent to become effectively "down-wind".

Long-term wind condition statistics can provide some indication of the relative likelihood of various wind directions at any one time, but these do not necessarily give an accurate indication of the seasonal variations that can occur. This has been clearly illustrated by the recent predominance of easterly winds over the 1998-1999 summer (the most infrequent wind direction based on long-term averages). This highlights the problem of using long-term wind averages in risk assessments, and future models may need to consider using climate models which predict future weather patterns according to El Niño/La Niña conditions.

### 4.7.2 Increasing vulnerability

There is an increasing recognition that the vulnerability of populations to natural hazards is exacerbated by certain social and economic conditions, and that it frequently increases with time. This was made evident by comparing the impacts of the 1945 and 1995-1996 Ruapehu eruptions. The 1995-1996 eruptions caused similar physical effects to the 1945 eruption but had considerably greater social and economic impacts. Increasing population and population density, levels of development, and a more technologically advanced infrastructure will continue to increase the level of risk to Auckland of future volcanic eruptions. This increasing level of risk will be reflected in factors such as increasing potential physical and economic losses, and the number of people that may need to be evacuated and/or resettled from any future eruption.

### 4.7.3 Insurance

A key determinant of the economic effects of such events is their impact on insurance markets. Any person who has fire insurance cover also has, for an additional premium, EQC (Earthquake Commission cover) and is insured against loss or damage to their home up to a set limit (currently $112 500 for dwellings and $ 22 500 for contents).

However, it is very difficult to establish the extent of insurance cover from the various insurers, in various locations. The "average" cover used in EQC studies is: residential building property insurance, 90% of dwelling inventory for the number of properties (*pers. comm.* EQC). These average coverage rates are somewhat verified by the total premiums received by EQC. What is not well known are the regional (or even local) variations (e.g. the Northland region is reputed to only have 33% coverage rates).

One risk with the onset of a volcanic crisis is that it may lead to changes in premiums or the cancellation of policies. This was the case in Rabaul (PNG) where Lowenstein (1988) notes

that there were "massive" increases in insurance premiums and loss of cover against volcanic and seismic risk. These insurance effects persisted through the crisis and flowed into a lack of finance from lending institutions for sustaining business activity and new developments. Also, during the recent Ruapehu eruptions (1995-1996) it is known that some insurers cancelled coverage in the region (either by activating their "7 days notice" clause or simply not renewing cover). At least one company continues to restrict volcanic insurance coverage in the region.

#### 4.7.4 Comparison with Auckland "Power crisis"

In February 1998 an extensive and lengthy power blackout hit Auckland City. Four major power cables, which supplied the city of Auckland with 440 kilovolts of electricity, failed, leaving only a 22 kV stand-by cable to supply Auckland's hospitals and emergency services.

The outage affected 8,500 businesses and over 60,000 people working in shops and offices. Emergency services initially urged people to stay out of the central business district, but some businesses remained open, with limited power supplies from portable generators. Overheated diesel generators caused several fires.

As well as workers, approximately 6,000 residents were advised to move out until power was restored. Little assistance was offered, and people with nowhere else to go were forced to use emergency shelters set up by the Auckland City Council in school halls.

Local officials warned of major health risks in the event of breakdown of water and sewerage supplies. Extra garbage services were scheduled to cope with the rotting food thrown away by restaurants, shops and residents whose refrigeration systems no longer operated. Port of Auckland turned away incoming ships and sent thousands of refrigerated containers with perishable exports such as butter and meat to other ports.

In the aftermath of the Auckland power failure considerable effort was spent in examining the causes of the failure. These are not pertinent to this study. However, the impacts of the failure can be considered to have some similarity to the effects of a volcanic eruption in the city and therefore, the way in which individuals and businesses coped is relevant, and can be used to assist in deriving parameters to assess the impacts.

Many of the individuals who lived in the central business district were able to find temporary accommodation with friends and relatives in other parts of the city. Some were forced to stay in motels or rental accommodation. A few were dependent on agencies such as the City Mission. When the blackout occurred, officials admitted that the blackout might last for up to three weeks. In the event, the outage lasted considerably longer, putting a considerable strain on people normally resident in the area.

As noted by Clive Manley from the Auckland City Council in a presentation to an Auckland Engineering Lifelines seminar (ARC, 1999), businesses are becoming more and more dependant on technology. The types of impacts to business that resulted from the power failure affected safety (lifts, lighting, fire alarms), health (loss of freezers and extra rubbish), building services (sewer and water), security (shops and offices) generators (fumes and fire), and business viability.

Business viability was an issue because of messages given to the public to stay away from the central business district (when it was assumed that the outage would be of short duration), and from the absence of large numbers of workers who were relocated or able to work from home. The best way to restore the economy was seen as being to bring people back to the area as soon as possible, while ensuring their safety. Once power was restored the City Council assisted businesses to run a number of promotions aimed at bringing the general public back into town. Despite these efforts over 400 businesses failed.

The main similarities between the Auckland power failure and a volcanic eruption are that the power crisis continued for a considerable length of time, and officials were unable to reliably predict an end to the crisis. There was considerable disruption to individuals living in the area, and business activity was severely affected. People moved out of the area, and some businesses were able to relocate on a temporary basis.

The key differences are that with the power crisis there was no physical damage to buildings, no long-term effect on structures or infrastructure, and minimal cleanup required. On the other hand, the amount of warning was very limited. Some of the strategies used to cope with the Auckland power failure would also be valuable for coping with a volcanic scenario.

# 5.0 SOCIAL VULNERABILITY

## 5.1 Introduction

The concept of vulnerability describes the combination of characteristics of a person or group in terms of their capacity to **anticipate**, **cope with**, **resist**, and **recover** from the impact of a hazard and which determines the degree to which a person or group's life, well-being and livelihood is put at risk by a disaster (Blaikie, et al., 1994; Hewitt, 1995). The relationship between these factors and the personal resources that contribute to reducing vulnerability is illustrated below.

| Vulnerability factor | Personal/group resource |
|---|---|
| **Anticipation** | *education* |
| | *awareness* |
| | *knowledge* |
| **Coping** | *physical & financial resources* |
| | *psychological resources* |
| **Resist** | *physical & financial resources* |
| | *nature & level of preparedness* |
| | *(physical & psychological)* |
| **Recover** | *support resources* |
| | *physical & financial resources* |
| | *psychological predispositions* |

All individuals and communities are vulnerable to volcanic hazard effects. As a general rule the level of vulnerability is inversely proportional to the degree of social integration (Britton, 1991). The more marginal the group, the greater is their vulnerability. Consequently, it is more appropriate to consider how certain personal and community characteristics interact with hazard effects to influence the manner in which risk is distributed throughout a community (Britton, 1991; Paton, 1996). The identification of these characteristics and the analysis of their distribution provides a platform for planning and implementing several reduction (e.g. identification of community needs, design of threat communication messages), response, and recovery (e.g. planning how scarce resources should be allocated and distributed) activities. This brief introduction indicates the mix of activities and approaches that can contribute to mitigation and response strategies. The next step is to define the community vulnerability characteristics that prevail within the area of interest and match intervention strategy to these needs and characteristics.

It follows from the discussion thus far that vulnerability cannot be viewed prescriptively. Rather the factors used to describe vulnerability represent a data set that must be interrogated

within a context defined by the goals of the process or exercise. For example, vulnerability data have different implications for developing mitigation, threat communication, and response and recovery management programmes.

Vulnerability reflects individual, group and community characteristics that are variable both between and within communities, and over time. Consequently, there is no such thing as an 'average' citizen or community. Vulnerability must be defined within a context described by the specific relationship between a hazard and the personal and community characteristics of those affected (Blaikie, et al. 1994; Bolin, 1989; Green, 1993; Paton, 1996; Tierney, 1989). Even if dealing with the same kind of hazard, differences in vulnerability characteristics within, and between, communities make each disaster, from a social vulnerability perspective, unique (Hewitt, 1995; Paton, 1996). While they interact at one level of analysis, conceptualising vulnerability within a range of contexts can assist planning and response management (Eranen & Liebkind, 1993; Gist & Lubin, 1989; Norris & Thompson, 1995). For example, vulnerability can be considered in relation to susceptibility to physical effects (e.g. in relation to the built environment), economic effects (e.g. loss of employment, economic activity), and social-psychological effects (e.g. stress, threat perception). Similarly, understanding the concept of vulnerability can be enhanced by considering its implication in the context of mitigation/reduction (e.g. threat communication), response (e.g. community self-help, resilience) and recovery (e.g. community mobilisation) activities.

Vulnerability analysis can be conducted at two levels. The first involves defining the manner in which hazard effects represent a threat to individuals and communities and impose demands upon them. It is these demands that must be anticipated, resisted, coped with and recovered from. While hazard effects can exert a (relatively) uniform effect on communities (e.g. volcanic ash will blanket a given area), the ease with which they can be anticipated, resisted, coped with and recovered from is a function of patterns of interaction between hazard effects and personal, community and psychological characteristics. The latter will be discussed later in this chapter. This section of the report commences with a discussion of the relatively more direct relationship between hazard effects and vulnerability.

## 5.2 Social Vulnerability and Hazard Effects

Fundamentally, volcanic hazards will affect communities by exposing them to specific consequences (Hartsough & Myers, 1985; Millar et al., 1999; Paton, 1996). This process is illustrated in the text.

Uncertainty is a prominent social stressor. Uncertainty will be high when faced with an event that is outside the experience of most community members, and is likely to be compounded when they try to assimilate the implications of the physical effects of an eruption, particularly

when attempting to understand the nature and implications of effects such as pyroclastic surges and lava flows. Social vulnerability will increase with uncertainty regarding the duration of the event, particularly if accompanied by evacuation or re-location. In addition, uncertainty about the threat posed could encourage self-evacuation. Uncertainty can also emanate from aftershocks and periods of heightened hazard activity.

There exist several physical hazard parameters whose characteristics may be difficult to predict and which may change over time. For example, social vulnerability during the warning phase preceding a volcanic eruption will be heightened by uncertainty with regard to predicting the location and number of vents until close to the time of eruption. In the absence of this predictive capability, it is difficult to specify the area likely to be affected. Similarly, it will be difficult to predict the duration of the eruption, the volume of material erupted, the rate at which it is erupted, and the composition of accompanying ash and gases. The uncertainty associated with the latter is further complicated by, for example, atmospheric conditions. Wind direction, and changes in wind direction over the course of the eruption are difficult to predict, with corresponding implications for anticipating those likely to be affected. Contingency planning will be required to anticipate and model the implications of changes in these parameters.

Physical parameters influence social vulnerability in several ways. For example, the warning period between the onset of seismic activity and evacuation and eruptive activity can vary. The length of the warning period, anticipated hazard consequences and other effects (e.g. seismic activity, media coverage) which manifest themselves during this period can affect social vulnerability in several ways. In general, a short warning phase limits preparation time and increases response anxiety due to, for example, family separation, the loss of valuable possessions, and increased reliance on others. A long warning period, or one which is not followed immediately by the onset of hazard activity, increases the likelihood of anticipatory anxiety which can interfere, at least in the short term, with threat communication. High levels of anxiety limit information uptake. Consequently, it may be inadvisable to distribute threat and preparedness information immediately following the first signs of hazard activity. However, the increased levels of attention that exist once the initial anxiety subsides provides a basis for increased receptiveness to new information about a threat, assuming the content is consistent with the needs and meaning systems of each community group.

Other characteristics associated with prolonged warning periods can affect vulnerability. For example, unpredictable and/or inconsistent effects (e.g. changes in number, frequency or intensity of earthquakes) and/or by message inconsistency (e.g. from different sources; friends, family, media, TAs/RCs, GNS) during this period will heighten psychological vulnerability. Ensuring consistency in the messages distributed, particularly through the media is important. On the other hand, a long warning period increases preparation time and,

assuming an appropriate level of readiness, it will be associated with a reduction in response stress during and after an eruption.

The visibility of physical effects such as lava fountains and ash clouds will, as a consequence of, for example, their threat to properties and health, be a prominent source of anxiety and will attract considerable media attention. Media coverage of physical effects and their implications, if not carefully managed, can, through the operation of social amplification processes, heighten anxiety during warning periods, particularly when dealing with threatening events whose nature is characterised by uncertainty (Johnston & Paton, 1998). Social amplification can prolong psychological vulnerability, generate anger at authorities, lessen commitment to future activities, and lessen the perceived credibility of administrative and scientific authorities.

Vulnerability is heightened when communities encounter multiple threats. Volcanic hazards can expose communities to several distinct effects, including pyroclastic surges, ballistic impacts, ash falls, gases, and lava flows. In addition, these effects can generate other, secondary consequences and result in, for example, communities having to deal with ash effects on properties, ash polluting water supplies, loss of utilities, and threats to public health. The degree of threat posed by hazard effects also varies with their visibility. For example, the perceived threat attributed to an ash cloud will be less than that attributed to the ash when it enters the water supply because the threat becomes less visible and less amenable to individual action.

Hazard experience can result in the period of vulnerability extending beyond the period of cessation of physical activity. For example, during the post-event period, hypervigilance to threat cues associated with hazard effects increase the possibility of otherwise benign environmental events being perceived as threat (e.g. ground shaking from the nearby passing of a heavy truck). This problem may be particularly acute for some groups (e.g. young children, people with disabilities, elderly persons). Media coverage, and its role in the social amplification of threat and risk in particular, will play a substantial role in this process. This issue highlights the need for media management and for information on hazard effects and its social consequences to be distributed during and after eruptions

With appropriate management, the media can play a prominent role in educating the public about volcanic hazards, facilitate region-wide communication, and adapt material on the nature and implications of hazard characteristics to fit the needs of different groups within the community (Ronan & Johnston, 1999; Johnston & Paton, 1998). This educational role will be important in the process of translating terms such as pyroclastic flows and ballistic impacts to ensure public understanding of volcanic hazards and to broadcast information when most appropriate. Few people are likely to remember information covering all issues.

Consequently, broadcasting and publishing information will ensure that it is provided at a time when it will be most useful.

Ash can influence vulnerability in several ways. While its most obvious effect is as a consequence of the damage it causes to buildings, the relationship between threat visibility and perceived vulnerability is more complex. For example, it can pose a threat through its perceived effect on water quality, health, and its corrosive qualities, even if it does not pose a direct threat to the public. Threat communication must address the needs that arise from the public perception of the threat, irrespective of the validity of their concerns from a professional perspective (Lindell, 1997).

Vulnerability to ash hazards is linked to certain construction parameters. Pitch angle is a critical determinant of the vulnerability to roof collapse. Ash can obviously slide off steeply pitched roofs. Even moderate pitches can be less susceptible to collapse than flat ones. Obstructions such as parapets, roof tanks or solar panels may cause accumulation of ash. Roof pitch may have implications for social vulnerability directly (e.g. through direct damage) and indirectly (e.g. differences in distribution of damage as a consequence of differences in roof pitch). While ash coverage may be relatively uniform, its social impact will be influenced by factors such as roof pitch, a factor over which community members have no control (at least in the short term). Apart from its proximal effect on community members, the dissemination of information on this issue could constitute a source of stress and anticipatory anxiety, increasing psychological vulnerability.

Social vulnerability is influenced by the nature and severity of direct and indirect losses from the vulnerability of the built environment to volcanic hazard effects. The physical parameters of volcanic hazard consequences increase the potential for damage/destruction of property within a specified zone of impact. Direct losses increase vulnerability, as does the risk of physical injury (e.g. from ash inhalation). Vulnerability will increase according to the level of damage sustained, but this may not be evenly distributed throughout the affected area. Uneven distribution could result from, for example, differences in construction quality, construction suitability (e.g. roof pitch), and state of repair/maintenance. The distribution of impact can also be affected by topographical factors (e.g. whether building is on a hill or in a valley). Response/recovery vulnerability is also influenced by, for example, the extent of damage, the meaning of the loss (e.g. of valued possessions, owned versus rented accommodation), re-location time, adequacy of insurance, time taken to re-build and the need for permanent re-location.

Uneven distribution of impact is itself a vulnerability factor (Paton, 1996). Because uneven distribution of physical impact reduces sense of community and commitment to community-related activities it can heighten vulnerability during the recovery period (e.g. through the

manner in which financial and other kinds of assistance are distributed). Because aid distribution tends to be based on physical parameters, rather than including a component related to psychological distress, recovery assistance can constitute a 'response generated demand' (Quarantelli, 1985). Perceived inequity in the allocation and distribution of assistance becomes a stressor and can lower commitment to community recovery initiatives (Millar et al., 1999; Paton, 1996). It can also affect the quality of relationships with administrative agencies and may lessen commitment to future mitigation activities.

Thus, physical hazards can generate direct (e.g. from damage) and indirect (e.g. from uneven distribution of damage) effects on social vulnerability. Acknowledging the relationship between physical and social vulnerability is central to comprehensive emergency management. This approach facilitates the development of plans that systematically link reduction (e.g. through education about the nature of physical volcanic processes, land use planning), readiness (e.g. understanding the nature and limitations of volcanic hazard effects), response (e.g. control of evacuation and re-location), and recovery (e.g. developing understanding of social stress associated with volcanic hazards and using this information to design educational and support programmes).

In general, hazard effects tend to exercise a relatively uniform effect over a finite geographical area. Social vulnerability is not, however, directly related to physical impact or consequences. As a result, social risk reflects the interaction between hazards and community and individual vulnerability characteristics. It is to a discussion of these factors that this report now turns.

## 5.3 Social Vulnerability Analysis

The analysis of community vulnerability and the development and delivery of interventions to manage community vulnerability must be conceptualised and managed in a contingent, rather than a prescribed, manner. This report will describe the assessment and description of the community vulnerability within the Auckland region in relation to:

1) the development of an interactive model of risk comprising built, social and physical elements;
2) the sensitivity of risk estimates from a social vulnerability perspective;
3) the validity of the model within an all-hazards framework;
4) the development and evaluation of policy and planning recommendations; and
5) the development of the model as an interactive educational tool.

## 5.4 Risk modelling

### a. Parameters used

For this project, a three-tiered model of vulnerability was used to frame the vulnerability environment. Under normal circumstances the majority of community members are able to deal with the demands made upon them. When a disaster strikes a substantial increase in atypical and intense demands affects coping ability and renders some sections of the community more vulnerable to the physical, social, psychological, health and economic effects of hazard impact. Vulnerability was initially described with respect to demographic, community and psychological factors. From this initial framework, parameters were selected for the vulnerability analysis on the following grounds:

- extent to which a parameter represents a fundamental unit of vulnerability;
- measurement issues;
- ease of measurement;
- access to data with minimal assumptions;
- level of parameter variability; and
- the utility of parameters with respect to their implications for risk/threat communication and response/recovery management.

In the context of the above criteria, demographic variables were selected for this preliminary analysis. Demographic factors describe individuals/communities with respect to their capacity to anticipate, cope with, resist, and recover from the impact of a hazard at a fundamental level (i.e. it is immutable over the short term). A consequence of this is that it minimises having to make inferences regarding the interpretation or meaning of the data. Demographic data was readily available from existing and recent databases and could be used directly. The tangible nature of demographic vulnerability data renders it particularly appropriate for planning and policy development.

In comparison to community and psychological factors, demographic variables are less open to short term variation, rendering them more appropriate as a starting point for risk assessment and for regional planning. Finally, there is more extensive literature on the implications and limitations of demographic variables for developing risk communication and response programmes.

Demographic indices provide a conservative estimate of vulnerability which, in the event of an eruption occurring, will fluctuate depending upon the presence or absence of other community and social psychological vulnerability variables (see below). The lack of any database capable of furnishing data on the latter variables precludes their inclusion other than through judgement and inference regarding their possible influence. While these variables are known to affect vulnerability, their role in this capacity within the Auckland region can,

until they are systematically examined and assessed, only be inferred and will be used here as secondary data and to illustrate areas for future work.

For these reasons, demographic factors were selected as the parameters for defining social vulnerability within the Auckland region. While the analysis and primary conclusions are based on demographic data, other indices will be included at various points within this report to illustrate the contingent nature of vulnerability.

In regard to determining the risk status of Auckland region, the following criteria will be used:

- **Proportion of vulnerable groups**

  *By focusing on demographic indices, a reliable estimate of vulnerability can be obtained by examining the relative proportions of risk groups within any given area.*

- **The degree of dispersion of these groups throughout the region**

  *The complexity of the vulnerability environment is a function of the degree to which risk groups are dispersed throughout a given area. A highly concentrated group is easier to manage. Conversely, the more dispersed members of a group are, the greater the risk status because it demands more complex mitigation and communication strategies.*

On the basis of these criteria, from a social vulnerability perspective, Auckland could be categorised as a high risk area. As a proportion of the population as a whole and within each of the scenarios used for this project, high vulnerability groups (e.g. dependent children (<14), ethnic minorities, low socio-economic status) are represented at significant levels. In addition, the distribution of these risk groups reveals a highly complex vulnerability environment which compounds the risk.

**Selected variables**

Proximity to hazard effects renders geographical location a salient vulnerability variable. Hazard intensity can also be defined in relation to structural factors such as: topography and geographical/geological features; residential location features such as proximity; and housing type features (e.g. age, design, construction materials and methods, quality of construction and maintenance; state of repair). Geographical vulnerability is influenced by other factors, particularly socio-economic status. For this report, geographical location was prescribed by the eruption scenarios identified in ARC Technical publication No. 79 (Johnston et al., 1997).

Demographic vulnerability data were collated in map and tabular format. Each with a specific function. Maps were used to plot the distribution of vulnerable groups within each

5km impact zone. Data on the distribution of vulnerable groups will provide a basis for planning:

- community participation strategy
- information and community needs
- evacuation issues
- re-location or temporary settlement

For example, the specific needs of minority groups may be met by their relocation to areas where a similar population exists and where there is a greater likelihood of their accessing culturally-specific support resources.

The GIS maps plotted the distribution of vulnerable groups with respect to proximity to hazard (based on each scenario), distribution within each scenario, and distribution within the region. Overall, the vulnerability factors selected for this report were fairly evenly distributed throughout the region. This reveals a highly complex vulnerability environment for analysis, planning and information management. For example, the dispersed nature of group membership precludes the use of generic threat communication, mitigation, response and recovery programmes. Rather these will need to be planned to accommodate salient geographical differences in:

- vulnerability composition
- risk factors.

Geographical dispersed vulnerability signals the central role that community mobilisation strategies can play within the intervention planning and delivery process. This strategy is particularly important in the context of a relatively high and growing immigrant population. The issue of a substantial number of overseas tourists has not been considered directly here. This would complicate the vulnerability environment and planning process considerably.

While discussion is effectively restricted here to the 5km impact zones that describe the ash distribution/damage zone likely for each scenario, this conceptualisation will not accurately depict social impact within each zone. For example, threat perception and actual and anticipatory anxiety will extend the sphere of impact beyond these limits and may exert a region-wide effect even where physical impact is localised. This reflects the operation of the 'ripple effect' which describes how the social impact of hazard effects can extend beyond the point of impact and affect a wider body of the population as a result of their possessing a physical, social or psychological association with:

- the event;
- its location; and/or
- those directly affected.

As a result, a given eruption can affect a far greater number of people than might have been anticipated from the nature of the event itself or from the location and boundaries of physical hazard activity. This phenomenon can be extensive when, for example, cultures with extended families are dispersed geographically or where hazard effects destroy culturally significant icons. Acknowledging this 'ripple effect' is a very important aspect of vulnerability analysis, mitigation and response planning. On the basis of the above criteria, socio-economic status, age and ethnicity were the variables selected for this analysis.

### 5.5 Socio-economic Status (SES)

The distribution of power, status and resources, social inequality, and community participation suggest that those with higher socio-economic status (which is associated with material prosperity and better physical and psychological health) are better placed to cope with disaster impact (Britton, 1991; Cohen & Ahearn, 1980; Gibbs, 1989; Green, 1993). Resource availability, and resource acquisition ability, facilitates both preparation prior to impact and opportunities to protect and buffer themselves when an event occurs.

Socio-economic status influences locational choices as well as resource availability and political influence (Britton, 1991). For example, the members of lower socio-economic groups may experience greater vulnerability because housing is more affordable in higher risk areas. It is also important to acknowledge that people with low socio-economic status may be particularly sensitive to disruptions to societal and economic activities, even if not affected by hazard impact directly (e.g. those in part-time, casual or seasonal employment are more at risk of employment loss). Consequently, the occurrence of a disaster in their vicinity can further erode their economic, material and psychological resources, increasing immediate and longer-term vulnerability (Britton, 1991; Millar et al., 1999).

Socio-economic factors can influence peoples' attitudes and reactions to stressful situations, and thus their vulnerability, in several ways. Socio-economic status influences patterns of help seeking (Paton, 1996). For example, persons in lower socio-economic groups are generally more:

- inclined to seek medical rather than psychological assistance for mental health and adjustment problems; and
- likely to seek assistance from within their community.

As a consequence, the management of adjustment problems requires that liaison mechanisms are established between health and counselling resources. Mitigation, threat communication and response strategies are likely to be more effective if channelled through cultural/community agencies (Paton, 1996).

People in middle and upper socio-economic groups tend to be more aware of, and less likely to resist, accepting help when needed (Paton, 1996, 1997). The members of this group would be more appreciative of the long-term beneficial consequences of the early use of services. They are also more aware of, and able to meet the costs associated with the implementation of, preventative and mitigatory strategies. Socio-economic status (SES) will also relate to educational level and likely level of awareness of risks and what to do about them. SES affects the readiness with which individuals accept help voluntarily for emotional distress and other kinds of resource loss (Bachrach & Zautra, 1985; Millar et al., 1999; Paton, 1996). Strategies used to advise community members of the potential consequences of disaster and the manner in which support services are administered must be adapted accordingly.

For this analysis, socio-economic status was assessed using Deprivation Index (DI) scores (Salmond et al., 1998). Given its constituent categories, the DI appears to provide a good measure of socio-economic status and subsumes several relevant indices of vulnerability (e.g. low income, no qualifications, beneficiaries). The risk status of the region will be assessed in relation to the proportion of individuals described by High Deprivation Index scores. This was defined as a DI score of 6 and above. The greater the proportion of 6+ scores the greater the risk status of each scenario.

Areas defined by a DI score of 6+ were evenly distributed throughout the region (Figure 6). Concentrations of high vulnerability groups, according to this criterion, were evident in Scenarios 2, 3, 4, and 5 (Table 9). According to Johnston *et al.* 1997, the Scenario 2 area is vulnerable to pyroclastic surges likely to cause severe damage to property, necessitating re-location. Similarly, the risk of pyroclastic surges and lava flows in Scenario 3, and lava flows, ballistic impacts and ash falls in Scenario 4 and 5 signals the high probability of evacuation and relocation in areas characterised by low socio-economic status. Periods of re-location could be prolonged and even permanent (e.g. as a consequence of total destruction or lack of insurance), increasing the risk of secondary psychological and economic stressors. High concentrations of 6+ groups were also evident in the area immediately adjacent to the boundary of Scenarios 2 and 5, signalling the possibility of high secondary vulnerability here (e.g. economic fallout from direct effects in other areas).

The data in Table 9 also reflects the relatively even distribution of SES vulnerability throughout the region, with Scenario 5 recording the highest proportion (55%). These data suggest that SES vulnerability is substantial. It can be inferred from this that a substantial minority of the population:

- will lack the resources to engage in appropriate preparatory and risk reduction strategies,
- are likely to possess low resilience, and
- are likely to perceive threat/hazard information as having a lower priority than other daily needs and concerns.

If hazard threats are acknowledged, the members of this vulnerability group are less likely to see themselves as having the resources/capabilities to act on this information. For example, recipients of state/welfare support are increasingly dependent upon external (vs. self-help) resources, making them particularly vulnerable if these resources are unavailable, lessening their resilience.

The destruction and disruption to the social and physical infrastructure caused by a disaster will affect the short- and long-term economic status of the community. Subsequent economic problems can magnify the social vulnerability status of most groups (Paton, 1996). This means that, in addition to its being a response and recovery problem in its own right, economic issues must be considered in relation to their wider social and psychological implications. In addition to factors relating to regional economic conditions, economic vulnerability is influenced by the capability of local and central government agencies (e.g. need for income support, grants etc) and charitable organisations to manage these consequences, particularly in the light of the revenue implications of lost productivity over a period of months or even years.

Economic vulnerability assessment would concern itself with defining, for example:

- the number of activities contributing to an economy;
- the diversity of these activities;
- the vulnerability of each to the hazards within a given area;
- the extent of recovery of each activity/hazard combination; and
- the time taken to recover.

Secondary analysis of these factors would then be undertaken to explore their social and psychological implications for the short and long-term vulnerability of communities and their constituent memberships.

Another economic issue that affects social vulnerability is the manner in which compensation funds are disbursed, particularly if disbursement decisions are made without community consultation and on criteria defined solely on the basis of physical/economic damage or loss. Compensation decisions should be made in consultation with the community and should accommodate members' perceptions of both social and physical disruption (Paton, 1996; Raphael & Middleton, 1987). Compensation issues should also be considered in relation to the relative distribution of pre-existing economic disadvantage. Disaster relief funds (however unintentionally) are often distributed in favour of those least likely to be disadvantaged (Britton, 1991). Compensation processes can compound social inequalities. In the process, they can increase the future vulnerability of those already disadvantaged, both in terms of increasing the prevalence of vulnerability indices (e.g. inadequate housing, unemployment).

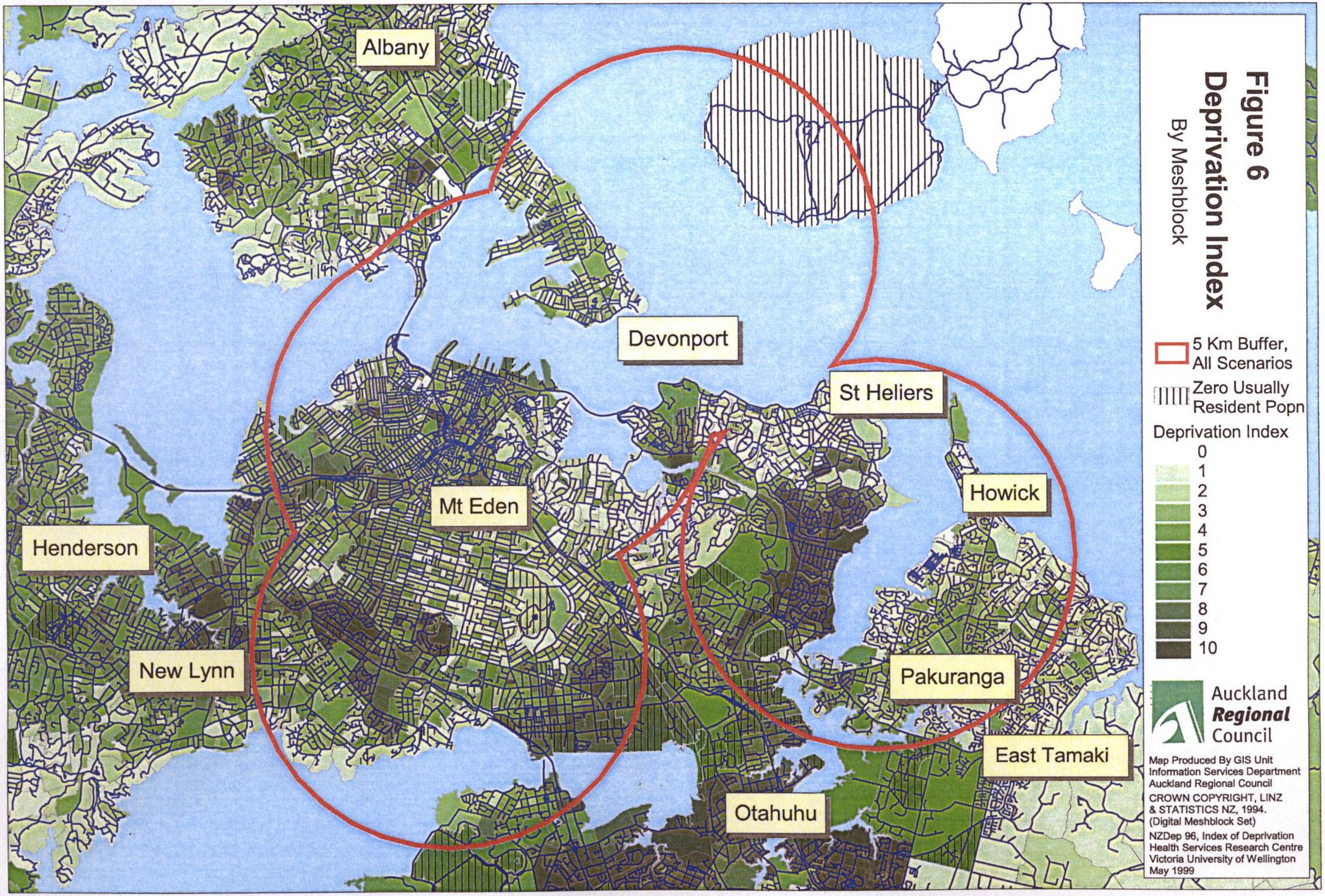


Figure 6
Deprivation Index
By Meshblock
5 Km Buffer, All Scenarios
Zero Usually Resident Popn
Deprivation Index
0
1
2
3
4
5
6
7
8
9
10
Auckland Regional Council
Map Produced By GIS Unit
Information Services Department
Auckland Regional Council
CROWN COPYRIGHT, LINZ & STATISTICS NZ, 1994.
(Digital Meshblock Set)
NZDep 96, Index of Deprivation
Health Services Research Centre
Victoria University of Wellington
May 1999
Albany
Devonport
St Heliers
Howick
Mt Eden
Henderson
New Lynn
Pakuranga
East Tamaki
Otahuhu

and through changes in the manner in which official agencies are perceived by community members (Britton, 1991; Johnston & Paton, 1998; Paton, 1996; Raphael & Middleton, 1987).

What is clear is that particular groups within society (e.g. minority groups, the elderly etc.) are the least able to withstand the financial and economic impact of disaster. It is important that we know:

- the conditions prevailing within communities prior to the disaster;
- the nature and distribution of vulnerable groups; and
- the implications of different hazard effects for social and economic disruption (and the relationship between them).

On the basis of the data described in Table 9, a substantial proportion of the population within each scenario is in full-time employment. The data suggest that disruption/loss of economic activity would exercise a significant impact on the area bounded by each scenario. Assuming that home ownership equates to insurance cover, damage and/or destruction to residential areas would make substantial demands on this resource. Secondary economic and psychological vulnerability would increase if insurance cover were inadequate, unavailable, or if there were delays in meeting claims. The complexity of the vulnerability environment, particularly in relation to the proportion of high deprivation, child, elderly and ethnic groups will make decision about aid distribution highly complex. Issues of, for example, procedural justice and fairness could generate secondary vulnerability and lessen commitment to future mitigation and preparatory activities.

In each scenario, some two-thirds of houses are owned (Table 9). From Table 9 it is evident that under these scenarios property damage could be extensive, and possibly substantial, in all areas. The adequacy of insurance for both property and contents is thus a significant issue in this context. While this issue was not examined empirically, their exist good grounds for concern in this matter. The vulnerability literature describes how certain groups (e.g. low SES, low income, elderly, ethnic minorities) may be under insured or not insured. Lack of, or inadequate, insurance, would compound vulnerability during the medium to longer term. Economic issues could also emerge if the eruption triggers a house price slump that leaves many owners over capitalised.

It is also pertinent to consider this issue in relation to the rental housing sector, and the insurance status of landlords (both state and private). For the private sector a separate, though related, issue here is whether, in the event of their property being severally damaged or destroyed, they would elect to re-build or leave this investment sector. Decisions on this issue will relate to the effects of an eruption on housing prices.

Psychological vulnerability would be affected by the availability of builders to carry out reconstruction work (cf. the problem encountered following the 1999 hail disaster in Sydney, Australia), and the time taken for this process to occur because it would lengthen the period of re-location and possibly expose people to other hardships (e.g. weather conditions over winter). On the other hand, the reconstruction phase could fuel a boom in building and building supply trades, including forestry.

### 5.5.1 Issues for Further Consideration

The data presented here reveals that a significant proportion of the population could be considered vulnerable to volcanic hazard effects as a consequence of their socio-economic status. However, additional research is required to investigate the selection of variables used to define SES for emergency planning. Similarly, more research is required to describe the relationship between these variables and, for example, preparation, threat communication design and effectiveness, and response management. The suggestions made here remain tentative until these issues can be systematically researched. This research should be conducted with a framework that integrates physical and social parameters to accommodate the influence of variables such as attitudes, perceived salience of hazard versus other social threats, housing quality and location, and attitudes to insurance. Members of the low SES group are likely to qualify for membership of other vulnerable groups. Interactions between group membership should also be accommodated within planning and research initiatives. As a consequence of their dispersed nature, community based strategies may be an appropriate vehicle for information/mitigation activities and evacuation/relocation planning. Community activities should include the development of support, outreach and helpline facilities.

## 5.6 Age Groups

Age is a prominent vulnerability factor (Cohen & Ahearn, 1980; Green, 1993; Green et al., 1995). Children and elderly people, because of their relatively greater dependence on other people (e.g. parents) and institutions (e.g. welfare agencies, superannuation), represent potentially high vulnerability categories. Several measures of age vulnerability (proportion of the population: under 5 years; 0 – 14; 50+; superannuitants) have been included here. This allows varying levels of conservatism to be accommodated when estimating vulnerability within the planning process. In general, vulnerability increases with the proportion of dependent children and elderly individuals within a given area.

### 5.6.1 Children

In addition to their being vulnerable as a consequence of their direct involvement in a disaster, children are also particularly prone to indirect victimisation (Paton, 1996, 1997; Paton & Sylvester, 1996; Ronan & Johnston, 1999). This occurs through exposure to the reactions of their parents, or significant others (e.g. teachers). Vulnerability and response

characteristics are strongly influenced by the child's level of cognitive development/age, patterns of up-bringing (e.g. physical/sexual abuse), and peer-group integration.

Two measures of 'child' vulnerability were used here (Table 9). Using the '0 -14' criterion (Figure 5), it is evident that vulnerability is high within each scenario and is evenly distributed throughout the region. A similar picture emerges when using the 'child <5' criterion (Table 9). These data, because they describe a highly dependent population, indicate a high level of vulnerability within each scenario and for the region as a whole.

Issues for consideration:

- provision of information to parents/schools on primary and secondary reactions in children
- development of school-based education/awareness/mitigation programmes
- liaison with community/minority groups to accommodate spiritual/cultural elements within these programmes
- business planning to accommodate family needs (e.g. family friendly policies and continuity plans that accommodate family demands on staff)

### 5.6.2 Middle Adult

Of the age groups, the members of this group are the least likely to be perceived as vulnerable. In general, at this stage in the life cycle resilience is high and this, coupled with accumulated life experience, facilitates their (relative) capacity to cope with extreme events (Paton, 1996, 1997). The members of this age group are also more likely to participate directly in relief and recovery activities. Participating in such activities can reduce short to medium-term (response and recovery) vulnerability and promote recovery by assisting the process of regaining a sense of control (Paton, 1997).

However, this should not be taken to imply that vulnerability is eliminated. The members of this group may be at risk because they qualify for membership of other vulnerable groups (e.g. SES, physical health problems). Even if not candidates for inclusion in other categories, the members of this group may still attain risk status. The demands of short-term coping, and/or involvement in relief/recovery activities, may result in problems only becoming evident some time after the event. Similarly family concerns and demands can heighten psychological vulnerability. Vulnerability may also be heightened by, for example, reappraisal of the future (e.g. questioning ability as a consequence of their reactions or questioning the desirability of remaining within a high risk area) or economic difficulties (e.g. temporary loss of work, increased risk of job loss).

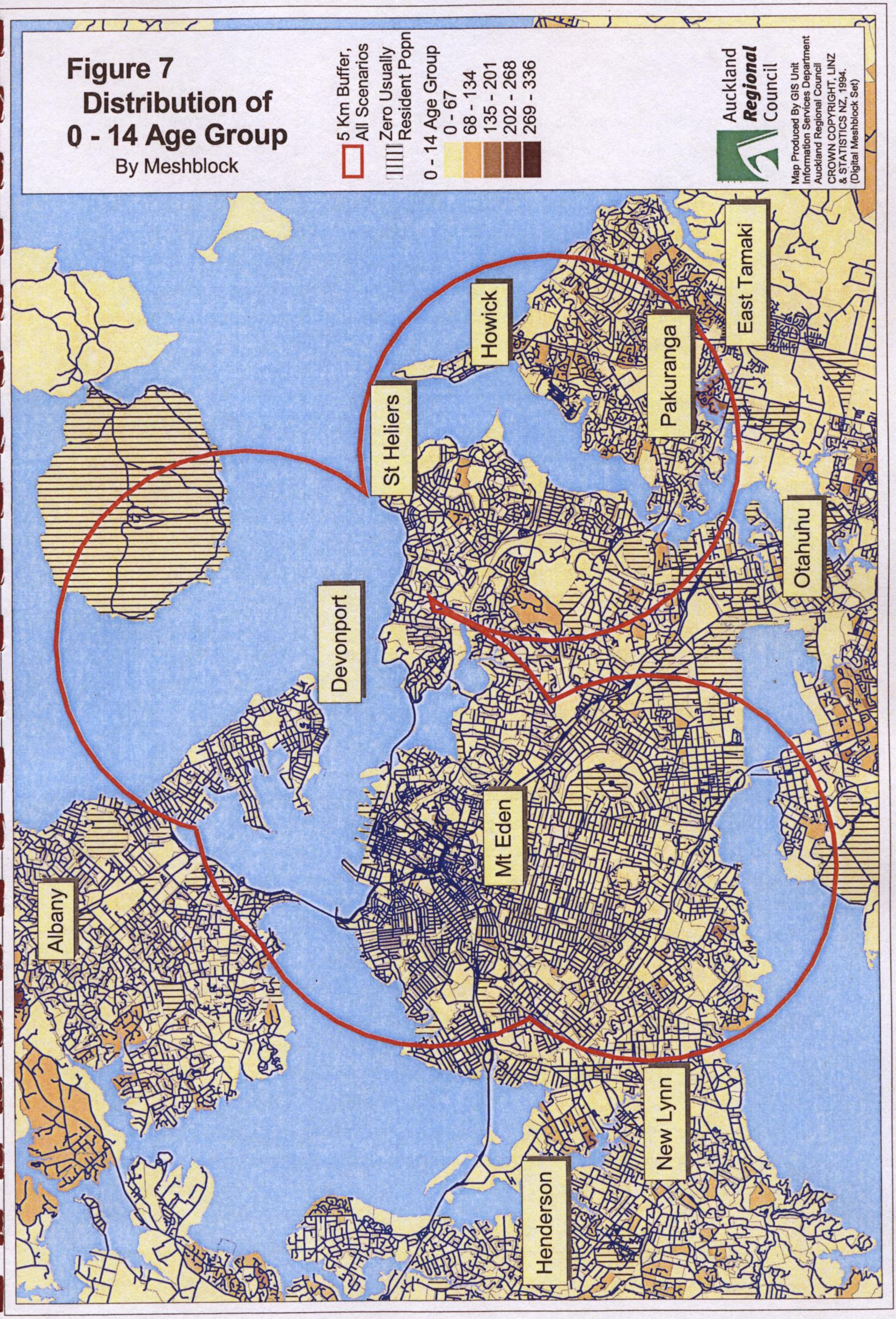



**Figure 7**
**Distribution of 0 - 14 Age Group**
By Meshblock

Within the Auckland region, members of the 25-49 age group are evenly distributed within each scenario and throughout the region (Figure 6), with relatively higher representation in Scenario 2. While the members of this group can generally be considered as low vulnerability, this interpretation should be considered in the context of the issues outlined above. The importance of this group within the workforce raises some additional issues. For example, they will be vulnerable to economic consequences that affect employment. Their high representation within the workforce also calls for business continuity planning to cater for human resource issues in a manner that facilitates business and personal recovery and accommodates recovery concerns (e.g. family issues).

### 5.6.3 Older Adults

Older adults, along with people with disabilities and minority groups, represent one of the most vulnerable groups within New Zealand society (Britton, 1991). As a group, elderly individuals are vulnerable to disaster impact because they:

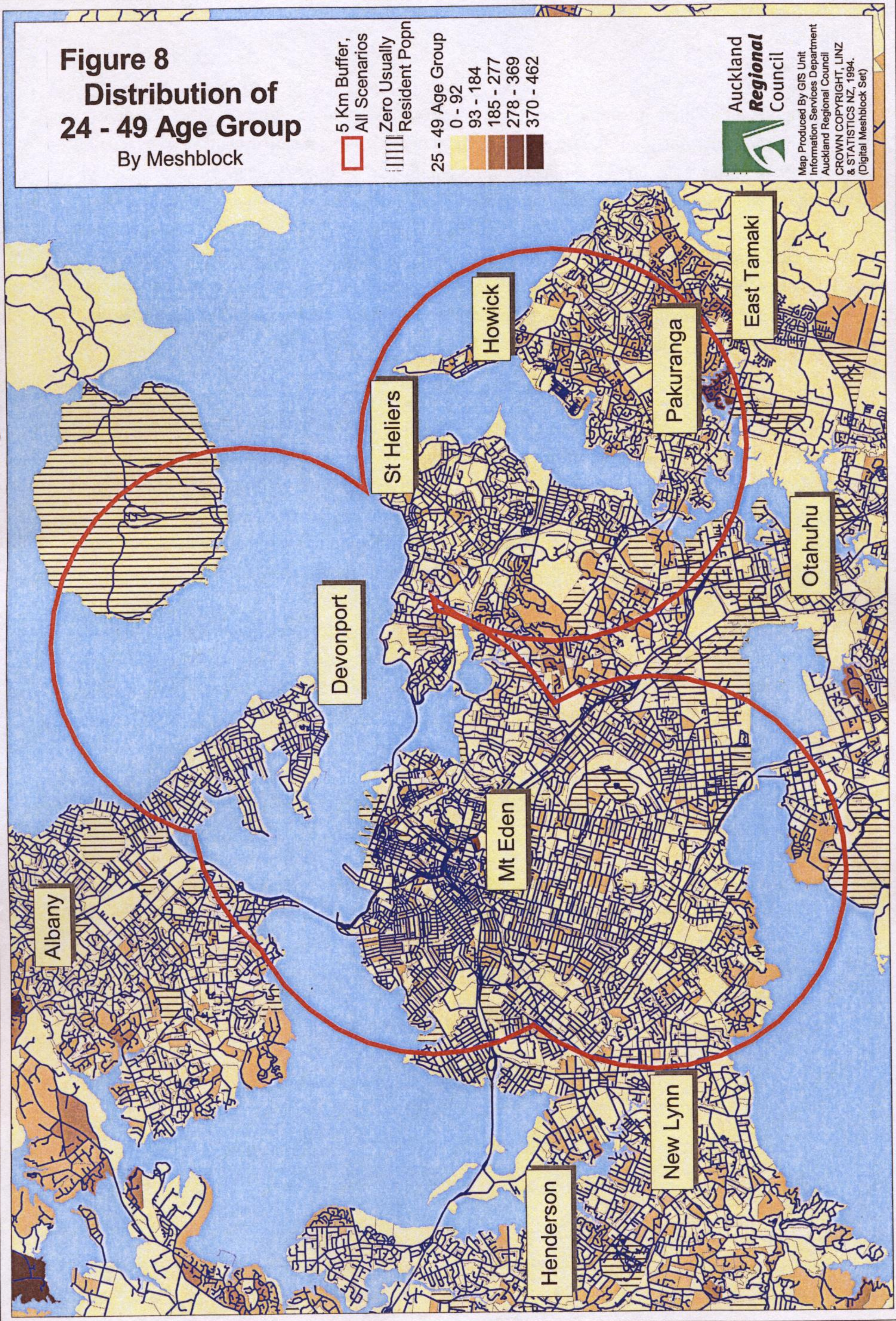
- suffer most from physical disabilities and health problems;
- lack mobility and rely on external assistance;
- are more socially isolated with limited social support and information networks;
- have low incomes and thus little economic or political power (although the 'grey power' movement has increased political representation);
- are less able to restore or replace damaged or lost property;
- can experience sudden and often irreversible decline in cognitive functioning (e.g. memory problems, confusion) following acute stress or injury.

Because acute stress can result in temporary, and sometimes prolonged, loss of physical and cognitive capacity, pre-disaster assessment of functioning may not provide a realistic measure of likely vulnerability. Members of this group are also particularly vulnerable to the stress of relocation (Cohen & Ahearn, 1980; Green et al., 1995; Lyons, 1991; Norris & Thompson, 1995; Paton, 1996).

With increasing age there is a concomitant drop in the likely adoption of preventative or hazard-reduction measures (Britton, 1991). For example, unless it reflects a long-established pattern, financial constraints lessen the likelihood that the elderly will be insured. Although their extensive life experience may increase their awareness of hazards, the very fact that they have had such experiences can instil within them a degree of scepticism regarding their risk status or the need to do anything about it (Britton, 1991).

In addition, the elderly are less likely to receive warnings of threats. They tend to have less regular access to information networks. Their consequent lower awareness of hazards and risks is further compounded by their limited access to social networks (Britton, 1991). This is

**Figure 8 Distribution of 24 - 49 Age Group By Meshblock**



a significant problem given the research findings that show that inter-personal discussion is a significant determinant of: hazard awareness; and decisions to act on warnings or to evacuate. Evacuation decisions for this group are also complicated by their reluctance to leave behind valued belongings and reminders of their life.

For older adults, occupational and social disruption can heighten vulnerability. Vulnerability can also be increased as a result of the loss of a sense of security within the community environment; difficulty adapting to retirement, and concerns about future economic stability (e.g. work, pension provision) (Paton, 1997).

Members of the population in the 50+ group were evenly distributed throughout the region, and marginally more heavily represented in Scenario 2 (Figure 7). The GIS maps reveal an overlap between membership of this group and high DI scores. While it was not possible to examine this relationship in detail, it can be tentatively inferred that that this relationship could reinforce the vulnerability status of the members of this group. This inference can also be extended to those residing in the area immediately adjacent to the boundary of Scenarios 2 and 5, signalling the possibility of secondary vulnerability emerging in this area.

The members of this category who are in the workforce are more highly susceptible to economic and social-psychological vulnerability than their younger counterparts, particularly following economic contraction. Those in the 60 - 65 + group become increasingly vulnerable from any threat to their economic integrity (e.g. loss/disruption to superannuation, being under-insured for damage/loss of property and belongings). Social-psychological vulnerability can be heightened by evacuation/relocation, loss of belongings, anxiety, concerns about retirement and, over the longer term, threat to sense of security in any environment.

The data in Table 9 reinforces the view that members of this group are evenly distributed. Two criteria were extracted to examine age-related vulnerability: the proportion of the population within the 50+ age group and superannuitants. Using the former criterion, the number of 50+ individuals constitutes slightly less than 1 in 10 of the population. While it represents a more tentative criterion of elderly status, data on the proportion of superannuitants (Table 9) indicates a relatively even distribution, with a significant minority of the population in each scenario being described as vulnerable, particularly in Scenarios 2, 3, and 4.

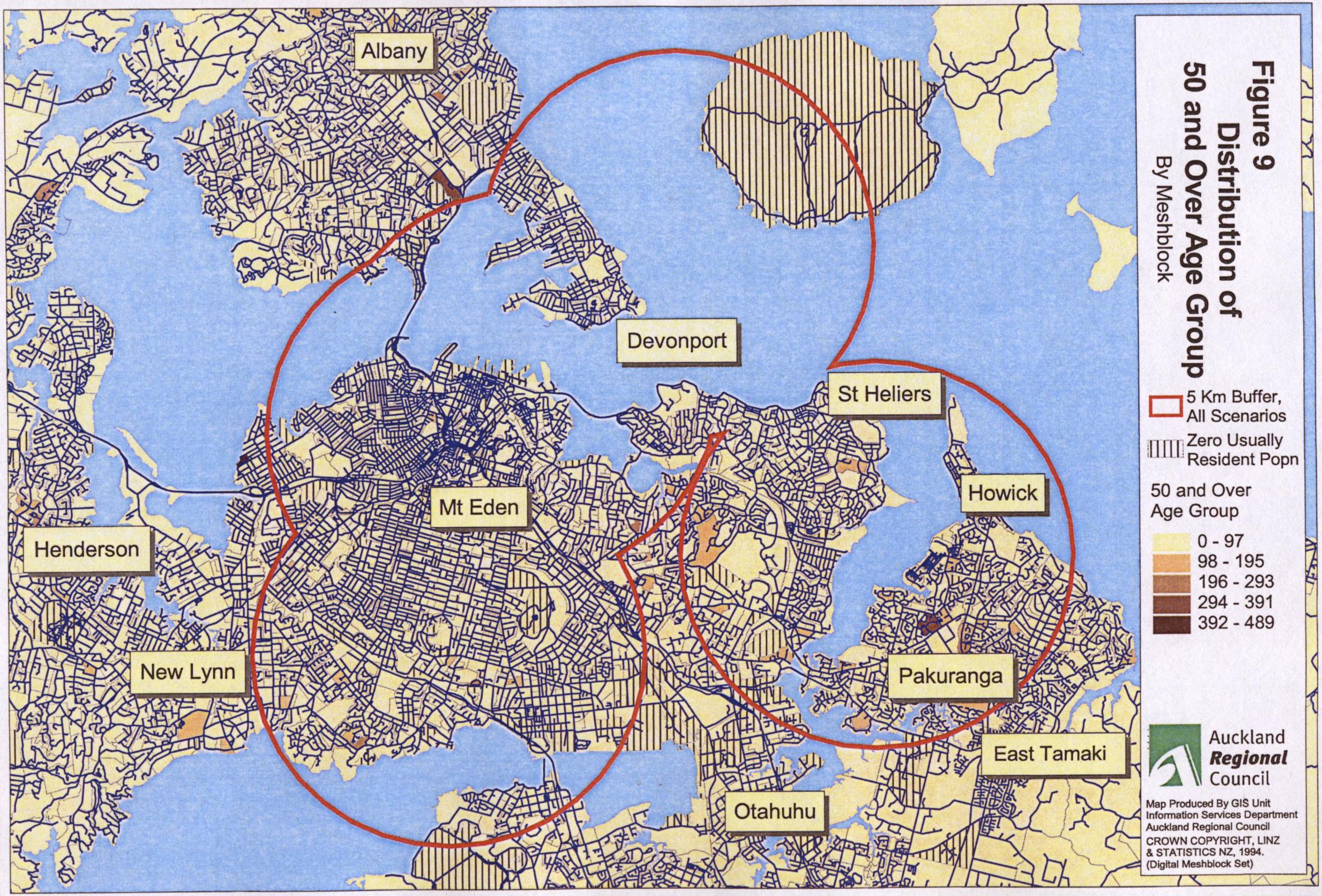


Figure 9
Distribution of
50 and Over Age Group
By Meshblock
5 Km Buffer, All Scenarios
Zero Usually Resident Popn
50 and Over Age Group
0 - 97
98 - 195
196 - 293
294 - 391
392 - 489
Auckland Regional Council
Map Produced By GIS Unit Information Services Department Auckland Regional Council
CROWN COPYRIGHT, LINZ & STATISTICS NZ, 1994. (Digital Meshblock Set)
Albany
Devonport
St Heliers
Howick
Mt Eden
Henderson
New Lynn
Pakuranga
East Tamaki
Otahuhu

### 5.6.4 Issues for further consideration

The vulnerability status of members of this group is highly sensitive to economic conditions, physical health status and disability. Additional research is required to gain a better understanding of the nature of age-related vulnerability, the implications of multiple-category membership, threat communication needs and media, and support and recovery resources. Developing this understanding, and using the information obtained to develop and implement mitigation and recovery programmes, will require liaison with gerontological, health and mental health resources. The vulnerability status of this group, and their relative isolation, requires additional research to be undertaken into mitigation/preparation strategies, including evacuation, safeguarding belongings, insurance, and empowerment.

## 5.7 Ethnicity

New Zealand is a multi-cultural society. Cultural differences, especially with respect to language and ethnicity, can significantly influence vulnerability (Gardiner, 1995; Minas & Klimidis, 1994;). Migration and resettlement in a foreign and culturally unfamiliar environment contribute to vulnerability (Minas & Klimidis, 1994), particularly in relation to events which evoke meanings and reactions similar to their earlier experiences (e.g. of volcanic eruption, equating evacuation warnings with persecution, or relocation with eviction).

Vulnerability is heightened by concurrent life stresses (e.g. economic). Interactions with authority figures and institutions, even about benign issues (e.g. being surveyed) can increase vulnerability. Prior experience of disaster or traumatic events can influence subsequent vulnerability. For example, within the Australasian region some 40% of refugees have experienced trauma (political persecution, torture) and a high proportion of Pacific Islanders have had prior and multiple experience of natural disaster. As a consequence of this history, certain groups can experience problems because media reports and popular film/TV coverage of disaster can heighten psychological vulnerability (Minas & Klimidis, 1994).

The experience of migration, exchanging a known for an unfamiliar culture, encompasses a complex set of factors that affect vulnerability. These include:

- socio-economic status
- working below education level
- higher than average unemployment
- poor quality housing and proximity to hazards
- changes in social milieu
- re-structuring of the social network
- family separation
- loss of contact with significant others

- physical and psychological isolation
- lack of necessary skills for the new environment
- inadequate knowledge of English language
- inadequate knowledge of the manner in which the new society and its institutions operate
- the need to adapt to the pressures of acculturation at personal and family levels

Expression of vulnerability and risk draws upon culturally relevant theories, myths, beliefs and meanings which are distinct to each culture (Minas & Klimidis, 1994). Understanding of natural hazards and the context in which they occur is similarly grounded. Perceptions of vulnerability occurs as a consequence of exposure to particular environmental events, the attribution of meaning to these events, and the cognitive, affective and physiological consequences of the particular attributions of meanings.

In addition, while both minority and majority groups are stressed by post-disaster relocation and inadequate temporary accommodation, the often close-knit nature of ethnic minority communities results in their members reporting relatively higher levels of stress when relocation decisions result in the break-up of established social units which would otherwise play a significant role in assisting coping efforts. The loss of these social networks constitutes a response generated demand and contributes to promoting or sustaining vulnerability over the longer term. Recent immigration may leave an individual without family or social support and result in their facing additional difficulties because of problems in knowing how to access support (Britton, 1991; Paton, 1996). A lack of support service capable of accommodating the (possibly diverse) needs (e.g. physical, social, spiritual) of constituent cultural groups will extend vulnerability status well beyond the period of tangible event impact. Members of ethnic minorities are predisposed to seek information, and to respond to requests, from within their own ethnic group. This highlights the need to utilise community/ethnic groups in mitigation and response planning and intervention.

When considering ethnicity as a vulnerability factor, it is important to acknowledge the differences between groups, rather than simply lumping them together on the grounds of their ethnic minority status. Although culture is commonly identified with ethnicity, they are not synonymous. The range of beliefs, values and practices within an ethnic community is broad. Uncritical use of terms such as 'Pacific Islander' or 'Asian' (as used in the census and other survey instruments) may mislead as much as inform because it fails to capture important distinctions (e.g. Fijian immigrants can be sub-divided into Fijian Christians, Indian Muslims and Indian Hindus) within and between groups (Gillard & Paton, 1999).

It would be a substantial task to describe all possible differences. A more economical approach is to consider the general dimensions along which groups will differ (Britton, 1991; Gardiner, 1995; Minas & Klimidis, 1994; Paton, 1996). In this context, ethnic minority

groups within New Zealand are likely to differ from the majority, and from one another, in relation to:

- language and custom (e.g. status hierarchies, information needs,
- preferred sources of information);
- world view (i.e. beliefs about disaster causation & responses);
- socio-economic status;
- family organisation and structure;
- participation in religious and other voluntary associations;
- coping resources and coping styles (some of which may be difficult
- to utilise if separated from community/family);
- political efficacy and trust in social and political institutions; and
- history of persecution (in their country of origin if refugees).

This list, and the one above, can provide a basis for identifying issues to be considered to structure liaison with ethnic groups and to guide the development of programmes designed to facilitate hazard/risk reduction programmes for minority groups.

A core factor in reducing vulnerability involves communicating relevant information to those required to act on it. Ethnic status also influences:

- hazards & risk perception;
- perception and content of preparatory, warning & mitigatory activities;
- the nature of an appropriate response for them;
- how response activities should be conducted; and
- the credibility attributed to agencies and sources of information.

### 5.7.1 Communication

Communication comprises both language and non-verbal communication. Many people do not have a common language within society. Even those who appear to have a reasonable grasp of English may have limited knowledge of vocabulary, grammar, syntax and the use of idiom in English (Minas & Klimidis, 1994; Paton, 1996). These problems will become more pronounced under stress (e.g. warnings prior to eruption where complex instructions must be understood and followed). Cultures can also be described in relation to prevailing patterns of communication and deviations from these ideal patterns can diminish the effectiveness of communication. Effective communication is thus more readily accomplished by using representatives of ethnic groups as mediators.

Assessment of needs and concerns and the communication of risk reduction information will be rendered less effective if there is wide divergence between emergency management professionals and the community concerning the nature of the threat, its cause, its expected course and outcome, and what should be done about it. Such differences must be explicitly

acknowledged and explored and resolved to ensure that both sides can work with a common understanding of the nature of the problem, the goals of mitigation, how the goals are to be achieved, and the possible outcomes (Docherty, 1999; Minas & Klimidis, 1994). Facilitating this outcome requires negotiation:

- elicit client's ethno-cultural understanding of the nature and origins of the hazard, its course and outcomes, and expectations about mitigation (e.g. discussions regarding building vulnerability could be interpreted as resulting in them getting better housing. A failure to meet these 'expectations' can affect relationships and lessen commitment to future activities).
- present, clearly and plainly, a conceptual framework that makes sense to the client, their understanding of the clients problem and their mitigation programme.
- if significant discrepancies in conceptualisation remain, return to step 1 & 2 until matters are clarified.

Ethnic group members can also be differentiated with respect to their first language and their facility with English. Language barriers may endanger individuals if it hinders understanding of warnings and preparatory materials and activities (Britton, 1991). In addition to increasing vulnerability, differences in language and custom, if ignored, will lead to frustration which, in turn, decreases communication effectiveness and promote dissatisfaction with information/service providers (heightening future vulnerability).

Language difficulties may not become manifest until after the disaster. The stress associated with hazard impact, or the anticipation of this impact, may reduce this capacity, increasing their difficulties in understanding emergency instructions or obtaining resources or assistance. In addition, periods of high stress are likely to result in minority groups becoming more close knit and looking to each other, rather than the legitimate authorities, for guidance (Britton, 1991; Minas & Klimidis, 1994).

### 5.7.2 Agency credibility and authority

The members of cultural minorities may be suspicious of help offered by "outsiders"; ignoring or rejecting help from these sources and accepting it only from family and close friends (Docherty, 1999; Minas & Klimidis, 1994; Paton, 1996). Culture can influence the perceived credibility of the agency and its representatives. If credibility is not established at the outset, poor compliance is likely and credibility will be further down-graded. Credibility is, in part, driven by the agency awareness of their clients knowledge and expectations for mitigation/response etc. Agency representatives can achieve credibility by responding in ways which convey understanding of clients' cultural construction of hazards/ consequences/outcomes, through their requests for culturally consistent responses from clients, and through congruence of mitigation goals as shared by agency and client (Gillard & Paton, 1999; Minas & Klimidis, 1994). This can be most readily accomplished by using

ethnic representatives and mediators and engaging in a dialogue with the community through the mediator.

Taken together, these issues signal the need to develop assessment, educational and advisory services through cultural representatives or facilities to ensure that they are designed to cater for specific cultural factors.

## 5.8 Ethnic Group Representation and Distribution

### 5.8.1 People of Asian ethnic origin

People of Asian ethnic origin are distributed at a low population density throughout each of the five eruption scenarios (Figure 10), with concentrations evident in Scenario 2 and 5. Particularly high concentrations are evident in the area adjacent to the boundary of Scenario 2. While the boundary provides a cut-off point regarding anticipated physical impact (e.g. damage to the built environment, environmental degradation, loss of utilities/amenities), social psychological vulnerability could extend beyond this boundary, increasing the size of the population at risk. Risk status is particularly acute amongst those with a history of persecution prior to coming to New Zealand. The latter will experience a high degree of anticipatory stress and may be highly suspicious of those in 'authority'. At a general level, the distribution of people of Asian origin overlaps with an area of low deprivation/high SES, which may lessen vulnerability to economic effects. Concentrations of people of Asian origin in other parts of the region provide a basis for planning relocation to areas where existing groups/resources could be used to facilitate the relocation process.

Further work is required to determine the nature and content of preferred support resources (which may be present within their immediate community). If the latter possibility is supported, the extent to which support resources are dispersed throughout the region will influence vulnerability and become an important planning issue. Further research into the extent to which members of this group possess a history of persecution (increasing their vulnerability) is also recommended. Further research is required to explore whether a history of survival under adverse circumstances in their country of origin may increase their resilience and render them better able to cope with shortages. Patterns of interaction between ethnicity and other vulnerability factors is also recommended. Once core vulnerability factors have been articulated, it will be possible to conduct research into the relationship between vulnerability and hazard awareness, threat communication and preparation.

### 5.8.2 People of Pacific Island ethnic origin

People of Pacific Island ethnic origin are distributed with a low population density throughout each of the five scenarios, with concentrations evident in scenarios 2, 4, and 5 (Figure 9). This view is reinforced when the data from table 1 is taken into consideration. The majority

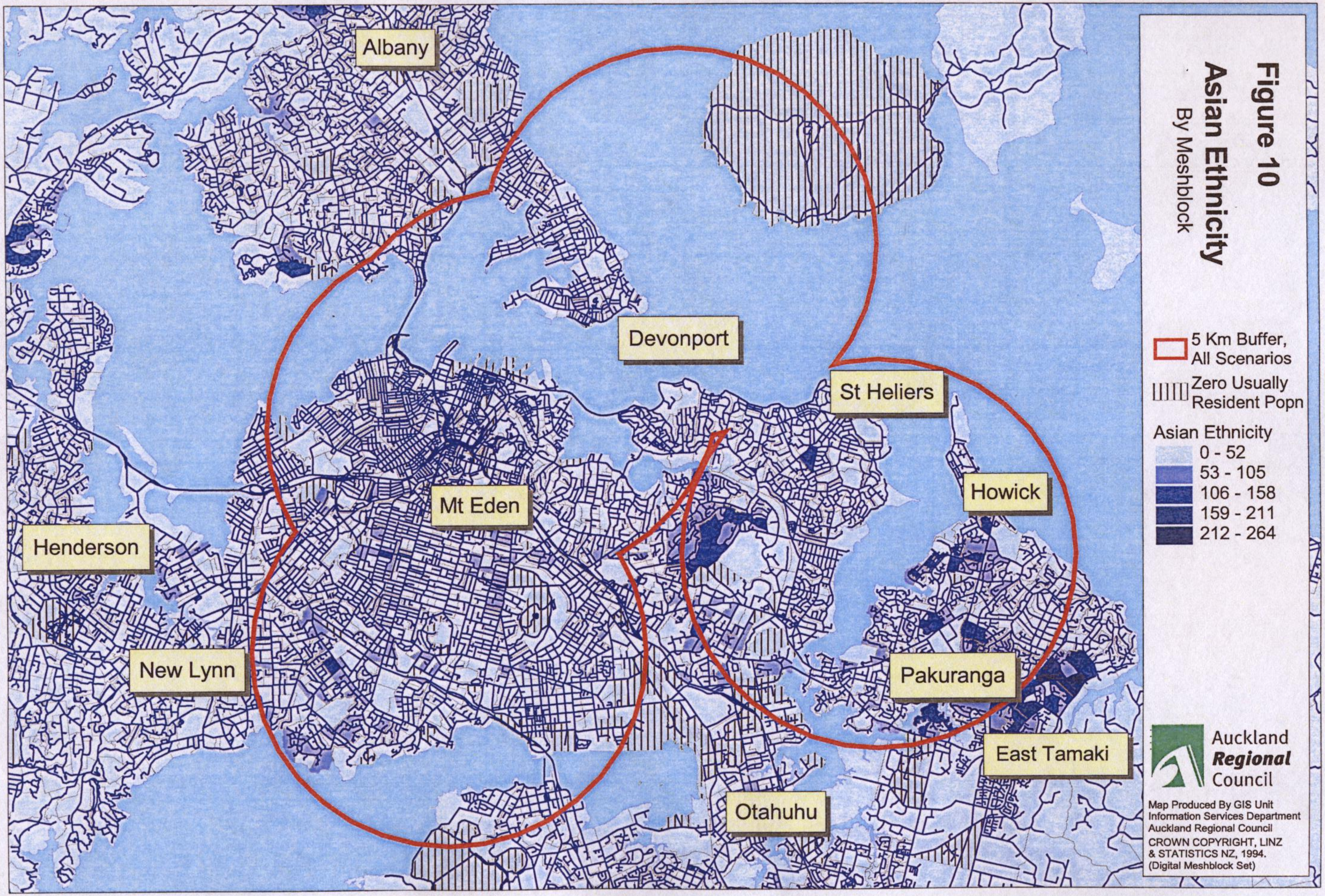


Figure 10
Asian Ethnicity
By Meshblock
5 Km Buffer, All Scenarios
Zero Usually Resident Popn
Asian Ethnicity
0 - 52
53 - 105
106 - 158
159 - 211
212 - 264
Auckland Regional Council
Map Produced By GIS Unit
Information Services Department
Auckland Regional Council
CROWN COPYRIGHT, LINZ & STATISTICS NZ, 1994.
(Digital Meshblock Set)
Albany
Devonport
St Heliers
Howick
Mt Eden
Henderson
New Lynn
Pakuranga
East Tamaki
Otahuhu

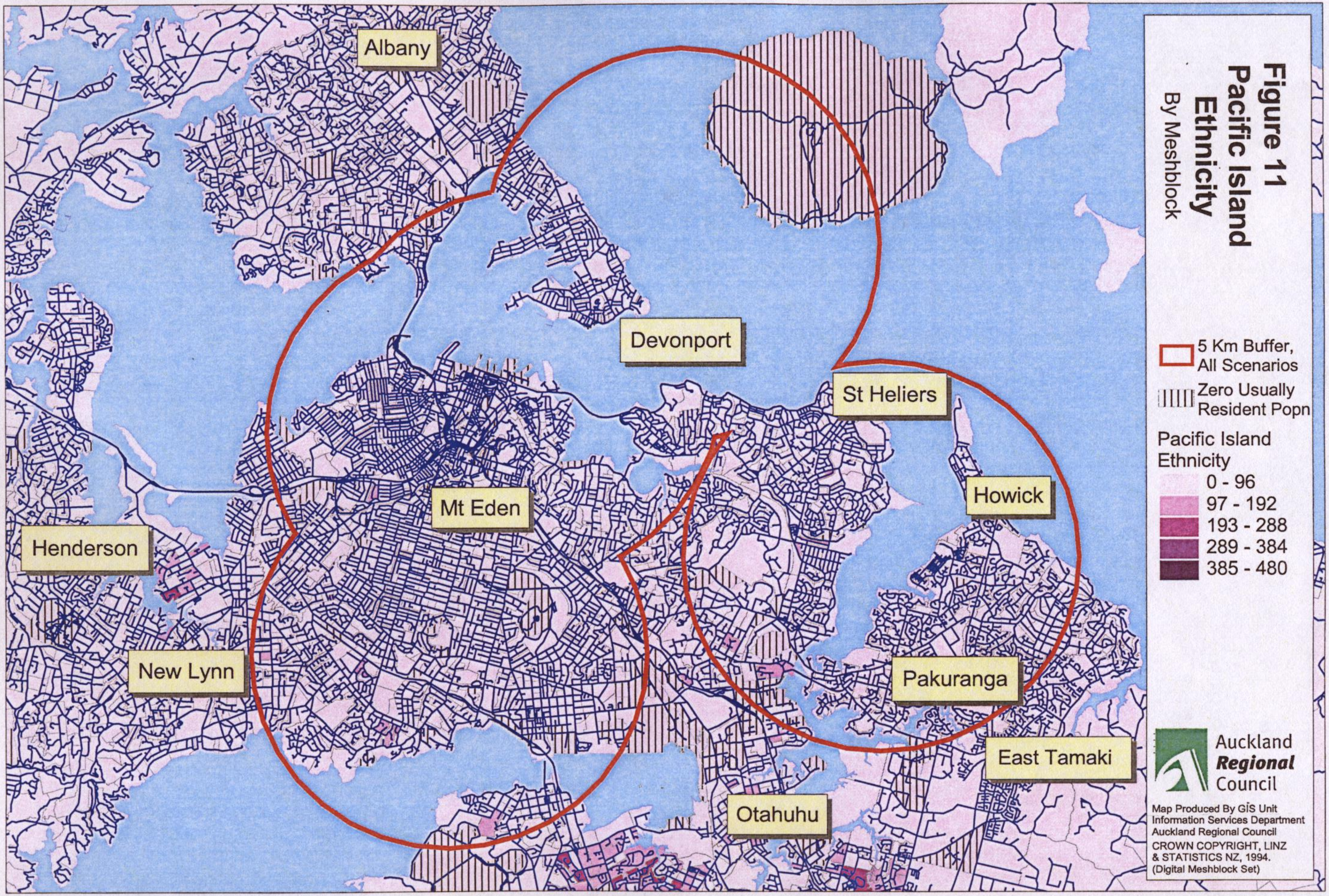


Figure 11
Pacific Island
Ethnicity
By Meshblock
5 Km Buffer, All Scenarios
Zero Usually Resident Popn
Pacific Island Ethnicity
0 - 96
97 - 192
193 - 288
289 - 384
385 - 480
Auckland Regional Council
Map Produced By GIS Unit
Information Services Department
Auckland Regional Council
CROWN COPYRIGHT, LINZ
& STATISTICS NZ, 1994.
(Digital Meshblock Set)
Albany
Devonport
St Heliers
Howick
Mt Eden
Henderson
New Lynn
Pakuranga
East Tamaki
Otahuhu

of Auckland's Pacific Islanders reside outside the prescribed 5km zones. The proximity of this population to the boundaries of Scenario 2 and 5 signals the potential for social-psychological vulnerability to substantially exceed that anticipated from an analysis restricted to the 5km circumference if an eruption were to occur within either of these scenarios. Further, the overlap between the distribution of Pacific Islanders and areas characterised by high deprivation index scores suggests that members of this group residing within Scenario 2, and those immediately outside the prescribed zone, could be highly vulnerable to economic losses resulting from hazard activity, even if not affected directly. The existence of concentrations of Pacific Islanders in other areas within the region provides a basis for devising evacuation and relocation plans.

For members of the Pacific Island community, the Church is a prominent community resource. Based on research undertaken in Fiji, religious faith is an important coping resource. However, religious denomination can act as both a support resource and as a stressor (Gillard & Paton, 1999). If provided with the necessary resources, and with appropriate liaison mechanisms in place, the religious institutions would be an appropriate provider of support, assistance, shelter, spiritual support and education and could contribute valuable information to the planning process.

Further work is required to determine the nature, extent and implications of religious or cultural fatalism. For example, research is required to determine whether and how fatalism affects the threat communication process and compliance with mitigation/preparatory activities. It will also be prudent to examine the extent to which increased physical vulnerability is offset by a reduction in psychological vulnerability compared with control-oriented cultures.

In addition to their religious affiliation, the extended family is a main support resource. Their distribution throughout the region raises issues regarding their ability to access this resource if affected/displaced by an eruption. Involvement with their immediate neighbours or community, unless of the same ethnic background, tends to be low, reducing their ability to seek assistance and support from their immediate neighbourhood. Provision of support thus requires re-uniting them with their respective Island cultural groups.

### 5.8.3 People of Maori ethnic origin

People of Maori ethnic origin are distributed at a low population density throughout each of the five eruption scenarios, with slightly higher representation in Scenario 2 (Figure 12). From Table 9, the even distribution of Maori across the region is evident, with relatively higher representation in scenarios 1 and 5.

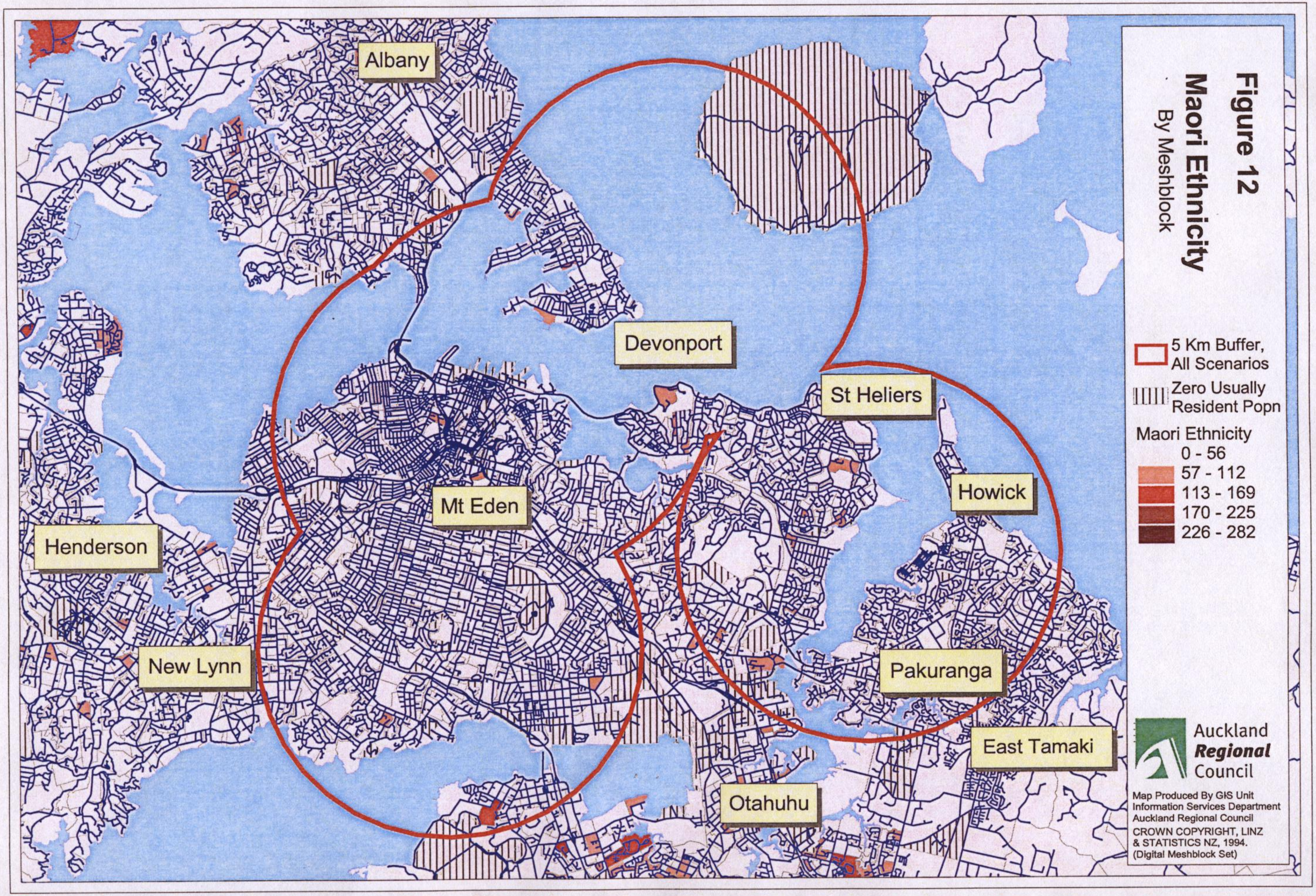



**Figure 12**

**Maori Ethnicity**

By Meshblock

As with their Pacific Island counterparts, major concentrations of Maori reside outside the Scenario 2 and 5 boundaries. Consequently, the size of the population vulnerable to economic and social-psychological effects would be greater than that described by the 5km zone. The coincidence between these concentrations and the distribution of low SES (high deprivation index scores) provides an additional indication of the economic vulnerability of this population. The existence of concentrations of Maori throughout the region provides a basis for evacuation/relocation planning.

For Maori, the family is a highly salient cultural characteristic, both with respect to their household and their extended family. The family (in the broadest) sense thus represents a valuable recovery/support resource and, conversely, family disruption/separation represents a salient secondary vulnerability factor. Support may be provided outside of home area on a Marae. Access to this resource could not be assumed, particularly if this were some distance removed from the home location, but planning access could be integrated into response planning.

Taken individually, Maori represent some 1 in 11, and South East Asian and Pacific Islanders some 1 in 8, of the population. Summing these data within each scenario reveals that between 30 - 40% of the population represents an ethnic minority. This reveals that, with respect to this vulnerability criterion, Auckland has a high risk status. The members of these groups are dispersed throughout the region, creating a complex vulnerability environment (for mitigation and response planning and implementation), reinforcing the high risk status for Auckland. This is true both within scenarios and across the region.

### 5.8.4 Issues for Further Consideration

The number and diversity of ethnic groups results in a complex vulnerability environment. There is a need for systematic research into the implications of ethnicity for disaster response in New Zealand. Ethnic diversity also implies a need to develop liaison mechanisms between group representatives and councils. A key issue here is developing ethno-cultural understanding of the origins/nature/meaning of hazards, the course and outcomes of mitigation (including clarification of mitigation/response expectations), and the ethno-cultural interpretation of hazard effects. Other issues to be considered here, and which may be ameliorated by the liaison mechanisms outlined above, concerns attitudes to authorities and its implications for mitigation. Using liaison mechanisms as a vehicle for planning will also make it easier to accommodate the inter-group differences, identify support resources/needs and monitor support needs and provision, plan evacuation/re-location/re-settlement, and develop and disseminate information in culturally appropriate formats. This strategy involves developing a dialogue with ethnic minority groups to build knowledge and databases regarding culturally-specific issues and using these outputs to discuss mitigation, risk reduction and response issues within a culturally-appropriate context. Local authorities could

provide the structure and information resources and provide an overarching, rather than a direct, management role.

**Table 9.** Distribution of vulnerable groups for each scenario (expressed as % the total population)

| | S1 | S2 | S3 | S4 | S5 |
|---|---|---|---|---|---|
| **Age** | | | | | |
| 0-14 | 22 | 22 | 21 | 20 | 23 |
| 15-24 | 16 | 15 | 16 | 15 | 16 |
| 25-49 | 39 | 39 | 40 | 40 | 39 |
| 50+ | 23 | 25 | 24 | 24 | 22 |
| **Full-Time Employment** | 56 | 46 | 58 | 54 | 56 |
| **Ethnicity** | | | | | |
| Maori | 12 | 10 | 10 | 8 | 14 |
| Pacific Islanders | 15 | 12 | 14 | 9 | 17 |
| Asian | 11 | 12 | 12 | 12 | 11 |
| **Dwellings** | | | | | |
| Owned | 66 | 67 | 65 | 67 | 64 |
| Leased | 31 | 29 | 32 | 30 | 33 |
| Free | 3 | 3 | 3 | 3 | 3 |
| **Household Constitution** | | | | | |
| Superannuitants | 39 | 42 | 42 | 44 | 37 |
| Child<5 | 33 | 32 | 32 | 31 | 35 |
| Solo Parent | 27 | 26 | 26 | 25 | 28 |
| **Household Income** | | | | | |
| <10K | 6 | 6 | 6 | 6 | 6 |
| 10-20K | 17 | 16 | 17 | 17 | 18 |
| 21-40K | 24 | 24 | 24 | 24 | 25 |
| 40-70K | 26 | 25 | 26 | 26 | 27 |
| 70K+ | 27 | 29 | 28 | 28 | 24 |
| **Deprivation Index (6+)** | 46 | 41 | 41 | 37 | 55 |

## 5.9 Sensitivity of Risk Estimates

The contingent nature of social vulnerability indices renders them subject to considerable variation. The sensitivity of social vulnerability indices is a function of:

a) hazard effect (e.g. duration, severity) variables; and

b) interaction with other vulnerability factors (demographic, community and psychological).

### Hazard Effect Variables

Exposure to hazard effect variables can affect vulnerability (Blaikie et al., 1994; Eranen & Liebkind, 1993; Hartsough & Myers, 1985; Paton, 1997). Hazard effect variables are numerous and their presence is hard to predict prior to the occurrence of hazard activity. Not only does this introduce an additional source of uncertainty into the planning and response management process, considerable knowledge and judgement is required to anticipate the contingent effects in risk. Prominent hazard characteristics are described below.

**Duration of threat/warning phase**

A short warning phase limits preparation time and increases response anxiety and stress. A long warning phase increases the likelihood of anticipatory anxiety which can interfere, at least in the short term, with threat communication. It does, however, increase preparation time and, assuming an appropriate level of readiness, reduce response stress.

**Nature of direct (e.g. physical injury, loss of home) and indirect (e.g. subsequent loss of livelihood) impact of threat**

The physical parameters of volcanic hazard consequences increase the potential for damage/destruction of property within a specified zone of impact. Direct losses increase vulnerability, as does the risk of physical injury (e.g. from ash inhalation).

**Severity of losses**

Following from the above, **impact vulnerability** is affected by, for example, level of damage, construction quality, construction suitability (e.g. roof pitch), and state of repair/maintenance. **Response/recovery vulnerability** is affected by, for example, the extent of damage, the meaning of the loss (e.g. of valued possessions), re-location time, adequacy of insurance, time taken to re-build, need for permanent re-location.

**Contrast between routine and crisis circumstances**

Vulnerability is increased if the physical impact results in disruption/loss of essential utilities and social infrastructure (e.g. power cuts, food, shortages, disruption to social welfare system). Being evacuated and relocated represents a significant social stressor.

**Nature of hazard effect**

For example, threat visibility affects perceived vulnerability. Ash fall per se may be perceived as less threatening than invisible changes to water quality when ash enters water system.

**Degree of uncertainty**

Vulnerability is increased if the warning period is prolonged, particularly if accompanied by inconsistent effects (e.g. changes in frequency of earthquakes) and/or by message inconsistency. Uncertainty can also emanate from aftershocks and periods of heightened hazard activity. Vulnerability will be influenced by the uncertain duration of exposure to hazard consequences and relocation.

**Time of occurrence**

Events occurring at night increase vulnerability. This coincides with a period of low psychological awareness, making instructions difficult to remember/follow. Daytime events can heighten vulnerability if they result in family separation.

**Exposure to traumatic stimuli**

Unusual smells, sights, sounds associated with event can prolong or trigger vulnerability if the person is exposed to them subsequently.

**Lack of opportunity for action**

The nature of volcanic hazard effects can preclude community involvement in their management or containment. Within western populations, opportunities for action to regain a sense of control which reduces vulnerability (cf. community involvement at Heimaey). This may not hold for the members of all ethnic groups. Further, having services/assistance imposed upon them by external agencies heightens vulnerability.

**Death/injury to community members**

In close-knit communities in particular, this can heighten vulnerability.

**Intense media interest**

Social amplification processes can heighten anxiety during warning periods, particularly when dealing with threatening events whose nature is characterised by uncertainty. Although depending on the nature of the event and its outcomes, media coverage can prolong psychological vulnerability, generate anger at authorities, and lessen commitment to future activities.

**Unrealised response expectations**

Vulnerability can be heightened if communities have inappropriately high expectations regarding ability of formal organisations to manage events.

**Uncertain or prolonged event duration**

Vulnerability is likely to increase with the duration of the event, particularly when its duration is uncertain.

**Inadequate resources**

Vulnerability is increased if individuals/communities lack the resources necessary for short-term self-reliance. In addition to things like food and water, this issue encompasses, for example, information about what is likely to happen and community participation.

**Single versus multiple threats**

Vulnerability is heightened where communities must deal with multiple threats. For example, communities may have to deal with ash effects on properties, ash polluting water supplies, loss of utilities, public health threat.

**Possibility for event recurrence**

Vulnerability can be heightened by, for example, after shocks. During the post-event period, hypervigilence to threat cues associated with the eruption increases the possibility of environmental events being perceived as a threat (e.g. ground shaking from the nearby passing of a heavy truck).

## 5.10 Interactive Vulnerability Effects

Vulnerability estimates are also sensitive to interactive effects. Two examples of this interaction effect are illustrated below using the 50+ and Ethnic Minority categories.

**50+ Factors affecting:**

| **Economic Vulnerability** | **Social-Psychological Vulnerability** |
|---|---|
| *Loss of employment* | *Loss of economic security* |
| *Loss of income (e.g. superannuation)* | *Property loss/damage* |
| *Insurance cover* | *Loss of belongings* |
| *SES* | *SES* |
| | *Level of education* |
| | *Self-efficacy* |
| | *Relocation/re-housing (temporary &permanent)* |
| | *Sense of security* |
| | *Social amplification* |

| | | |
|---|---|---|
| **Ethnicity** | **Factors affecting:** | |
| | **Economic** <br> **<u>Vulnerability</u>** | **Social-Psychological** <br> **<u>Vulnerability</u>** |
| | *SES* | *Cultural fatalism* |
| | *Employment status* <br> *(e.g. casual, part-time)* | *Cultural assimilation* |
| | *Age* | *Cultural/ethnic response demands* |
| | | *History of persecution* |
| | | *Access to support group* |

# 6.0 CASE STUDY: SCENARIO 4; ILLUSTRATION CENTRAL BUSINESS DISTRICT

## 6.1 Introduction

The purpose of this section of the report is to develop Scenario 4, which describes the physical effects of a volcanic eruption at the top of Queen Street, to include social and community aspects, effects on commerce and business, and aftermath or cleanup operations. Once this has been undertaken, parameters for evaluating the impacts of the scenario can be identified and their sensitivity explored.

Extending the scenario requires making a number of assumptions. To provide a social context, it is hypothesised that the event occurs in April-May, and that the eruption and cleanup therefore extends through the winter. Day 1 is ANZAC Day, with Day 26 (eruption) therefore being 20$^{th}$ May – a Wednesday. Scientific Alert Level 1 is declared on 3$^{rd}$ May (Sunday), and this is raised to Alert Level 2 on Wednesday 13$^{th}$ May. All schools and universities are in session. The weather is cooler, and while there may be some tourists in Auckland, it is not peak season for tourism.

If all scenarios are considered to have an equal likelihood of occurrence, Scenario 4 is a high risk scenario[4] because of the high magnitude of the likely consequences. Scenario 4 postulates potential exposure to several volcanic hazard effects (e.g. lava flows, ballistic impacts, and ash falls). Other factors that increase the likely consequences are the number, nature and distribution of risk groups within the affected area. Moreover, an eruption affecting the CBD is likely to generate substantial secondary vulnerability, increasing the risk status associated with this scenario. For example, disruptions to, or loss of, businesses and commercial activity will affect ancillary services (e.g. cleaning). The substantial representation of marginal groups (e.g. low SES, ethnic minorities) employed in these occupations could fuel an economic ripple effect and affect populations in outlying areas even if they were unaffected by direct eruption consequences. Secondary vulnerability may be further heightened by disruption/loss of small/medium businesses who are dependent on CBD activity (e.g. cafés, catering services, couriers, etc) or from loss of businesses for whom relocation is not a short-term option. In comparison to some other scenarios, a Scenario 4 eruption can be regarded as high risk because of the potential direct and indirect effects that heighten vulnerability within substantial sections of the population.

With respect to the composition of primary vulnerable groups, Scenario 4 can be described as follows:

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4 Risk being a combination of likelihood and magnitude of the consequences if the event occurs.

**Table 10.** Primary vulnerable groups.

| Group | Number | % |
|---|---|---|
| Age 0 - 14 | 126,843 | 20 |
| Age 50+ | 150012 | 24 |
| New Zealand Maori[5] | 51,993 | 9 |
| Pacific Islanders | 58,296 | 13 |
| Asian | 75,630 | 14 |

Within Scenario 4, 1996 Census data show that some 20% of the resident population is under 15, and 7% over 65, compared with 23% under 15 and 10% over 65 for the whole of the Auckland statistical region[6].

Of the approximately 14,000 dwellings within the scenario, 50% are owned and 50% are rented or leased. The area potentially directly affected under Scenario 4[7] has a resident population of 38,000. This provides an indication of the total number who could require evacuation. The population of Auckland City is 618,930. This wider area will be affected by uncertainty in early stages of the scenario, and some groups may require particular attention or even precautionary evacuation. Residents in the wider area will experience ash fall and may experience gas clouds, and therefore the cleanup area will be significantly larger than the area of direct impact. The above table indicates the number who, as a consequence of their high vulnerability status, would have special needs prior to (e.g. threat communication), during (e.g. adequacy of resource base) and after (e.g. support needs) the eruption.

At 1996 there were 497,164 jobs in the Auckland region; 383,394 full-time and 113,770 part-time. Fifty four percent of the population are in full-time employment. The CBD had 58,410 full-time equivalent jobs (13% of regional total), and 5,852 business units (7.5%), many of which are likely to be part-time positions. Seventeen percent of employed people living in Auckland City work in the CBD. Of the total residents in the area of impact 20,000 are employed (1,500 in cafes and restaurants, and 1,300 in education). Given that many of these people are likely to work within the CBD, it can be estimated that approximately 30,000 travel to work in the CBD.

5 Ethnic origin data for Auckland City 1996. Source "Regional Growth Forum: Employment Location in the Auckland Region"

6 Supermap. 1996 Census.

7 Freemans Bay, Auckland Central, Newton, Grafton, Herne Bay, St Marys. Ponsonby West, Ponsonby East, Grey Lynn West, Grey Lynn East, Surrey Crescent, St Lukes North, Arch Hill, Eden Terrace, Parnell East, Parnell West

The trend is for employment to be increasingly dispersed with the CBD giving way to other centres of employment. The CBD is increasingly specialising in business services and entertainment, with manufacturing moving to South Auckland.

Within a social vulnerability context, these data suggest that management strategies involve liaison/ co-operative working relationships with schools (0 - 14 group), ethnic groups and the business community. Local authorities, including Civil Defence and other responsible agencies (e.g. emergency services, welfare organisations) will have neither the knowledge base nor the resources to provide for the needs of these groups, making delegation of some disaster reduction and response activities (e.g. analysis of minority group information, response and recovery needs; and the development and delivery of threat communication) a necessary strategy.

To cater for the needs of children, this strategy could involve:

- ensuring that consistent information is available to schools, and for onward transmission to parents (e.g. regarding primary and secondary reactions in children)
- providing the structure and resources necessary for the development of school-based education/awareness/mitigation programmes (in conjunction with minority group representatives to accommodate spiritual/cultural elements within these programmes)
- liaison with the business community to advise on the planning issues that arise in developing business continuity plans to accommodate family needs

There are likely to be significant problems communicating with minority groups and managing their response and recovery needs. These problems arise because of the diversity of these groups and their distribution. Information about perceptions of threat, perception/understanding of hazard causes, the meanings attributed to hazard effects and agencies, the expected course and outcome of hazard effects and mitigation/response activities and how they should be managed can be obtained by entering into dialogue with ethnic group representatives.

A role for local authorities involves providing training for liaison resources, collating and co-ordinating information on hazard perceptions, and providing resources to support culturally appropriate intervention (e.g. threat communication, evacuation, re-location etc.) designed to cater for the unique needs of different risk groups. Comparison of data from various groups would identify areas of difference and similarity that can be used to optimise resource use. This strategy involves local authorities providing the structure, information, and resources, and fulfilling an overarching strategic management role.

The benefits of this approach extend beyond optimising use of management resources. For example, it reduces the likelihood of council activities being perceived as response generated

demands and complicating, rather than ameliorating, the social response and recovery process.

Some individuals will be members of several vulnerable groups. Therefore, in addition to the provision of specific information to cater for unique needs of each group careful attention needs to be paid to ensuring consistency of information and advice across groups. This process, including resource management and allocation, should be centrally co-ordinated.

The discussion of the scenario is based on the model postulated above.

### 6.2 Physical Scenario

The technical data for Scenario 4 in the 'Volcanic Impact Assessment for the Auckland Volcanic Field' has a vent location at the top end of Queen Street.

The lead-up to the eruption is tracked through as series of earthquakes. GNS staff are alerted on Day 8 (Saturday, 2nd May) and begin on-site monitoring on Sunday, 3rd May. Scientific Alert Level 1 is declared on 3rd May, and raised to Level 2 on 13th May. By Day 21, Friday 15th May, tilt levelling sites have been installed and the area of potential eruption has been isolated to an area within a 3 km diameter. While at this stage it is becoming apparent that there will be an eruption, the area is still not sufficiently well-defined for evacuations to be considered. Monitoring activity is undertaken at night with streets closed to traffic. Daytime activity in the CBD remains much the same as normal (consistent with the Scientific Alert Level 2 status). By 15th May the area is better defined, and schools may be closed or put on alert. The Scientific Alert Level is raised to 3 on Day 25, Tuesday19th May, approximately 16 hours before ground cracking occurs. At this point an eruption appears imminent.

On Wednesday 20th May the eruption occurs. Initially it takes the form of ground cracking with steam rising from the vents. Within the same day lava starts to flow down Queen Street, with fountaining to 100m. Over the day, the highest level of fire fountaining is 500 metres and projectiles are thrown as far as 750 metres beyond the vent. Tephra is deposited 3-5 km from the site (direction depending on the wind), and fine ash fall may extend 2-3 km beyond this. Gas clouds will extend over the whole of the city area.

Lava flow continues for 10 days (to 30th May) with the flow front estimated to be about 50 metres across. The lava flow reaches the Harbour with destruction of the ferry building and loss of the wharves between Wynyard Wharf and Tasman Wharf.

Over the next few months, there are occasional bursts of explosive activity, with the episode ending after about four months in mid September.

**Table 11.** A diary of the events leading up to the eruption

| Day (eruption minus) | Date | Day | |
|---|---|---|---|
| 1 (-25) | April 25 | Saturday | First earthquakes. GNS staff alerted. The media management plan is activated and media liaison is established to ensure that consistent messages are being disseminated. At this stage it is acknowledged that anxiety levels may preclude uptake of information. |
| 2 (-24) | 26 | Sunday | |
| 3 (-23) | 27 | Monday | |
| 4 (-22) | 28 | Tuesday | |
| 5 (-21) | 29 | Wednesday | |
| 6 (-20) | 30 | Thursday | |
| 7 (-19) | May 1 | Friday | |
| 8 (-18) | 2 | Saturday | |
| 9 (-17) | 3 | Sunday | **Scientific alert 1 declared** The GIS system is used to identify the nature, number and distribution of high risk groups. Community/ethnic liaison officers are advised and evacuation plans are held in readiness. Information resources are provided for minority group representatives. |
| 10 (-16) | 4 | Monday | Businesses are alerted and advised to review re-location and contingent continuity plans and prepare for implementation. Council business liaison consider resource and logistical issues. |
| 11 | 5 | Tuesday | |
| 12 | 6 | Wednesday | |
| 13 | 7 | Thursday | |
| 14 | 8 | Friday | |
| 15 | 9 | Saturday | |
| 16 (-10) | 10 | Sunday | |
| 17 | 11 | Monday | |
| 18 | 12 | Tuesday | |

| Day (eruption minus) | Date | Day | |
|---|---|---|---|
| 19 | 13 | Wednesday | **Scientific alert 2 declared**<br>This is accompanied by increased activity and anxiety, and high demands on helplines, information sources, and food supplies. |
| 20 | 14 | Thursday | |
| 21 (-5) | 15 | Friday | Tilt levelling sites installed (site identified to 3km).<br>Schools advised to consider closing. University notifies two week break. |
| 22 (-4) | 16 | Saturday | Some people leave for holiday homes or relatives in outer areas. |
| 23 (-3) | 17 | Sunday | Site identified to 1km<br>Evacuation readiness<br>Schools close. |
| 24 (-2) | 18 | Monday | |
| 25 (-1) | 19 | Tuesday | **Scientific alert 3 declared.** |
| 26 | 20 | Wednesday | Ground cracking begins<br>Lava starts to flow down Queen Street, with fountaining from 100m to 500 m occurring. Projectiles are thrown as far as 750 metres beyond the vent. Tephra is deposited 3-5 km from the site (direction depending on the wind), and fine ash fall may extend 2-3 km beyond this. Gas clouds extend over the whole city area. |

## 6.3 Social and Community Aspects

### 6.3.1 Greater Auckland

On Day 7, 3rd May, Scientific Alert Level 1 is declared. This is reported by the national and local media (who have already referred to the swarm of earthquakes). Many people living and working in Auckland feel uneasy about the extent of the activity. Some in-depth reporting discusses the nature of the Auckland Volcanic Field, but most reporting is simply news items. Reactions occurring at this stage range from anticipatory anxiety to denial, both of which affect information uptake.

The media response plan is mobilised with the aim of ensuring consistency and accuracy in media information and using the media as an education resource. Liaison with various media would attempt to provide information appropriate for the needs of minority groups.

Concerns and anxiety are particularly high amongst certain minority groups (those who are recent immigrants and, particularly, those with a recent of history of persecution) and amongst overseas students (many of whom are separated from family for the first time and do not have access to normal support resources). The GIS systems are used to identify the nature, number and location of minority groups and other vulnerable groups to gauge logistical needs. This resource can be used to define social vulnerability in response to eruptions occurring in different locations and involving different levels of impact.

Liaison with ethnic minority representatives advises them of the situation and what is likely to happen. Care is taken to ensure they can translate information to fit the needs of specific groups and deal with their specific problems. While being advised that they are not required as yet, the consultative process reviews evacuation plans, and ensures that the communities are in a state of readiness (including the logistics of evacuation and re-location and the identification of support resources).

Elderly individuals often have health and mobility problems; rely on external assistance; are socially isolated and may have limited access to normal channels of communication; and, under acute psychological stress, may experience intellectual difficulties that make comprehending and acting on threat information more difficult. Special attention is directed to meeting their needs at this stage. This includes dealing with anxieties relating to information/warnings and media coverage and concerns about their home and belongings.

Attention is directed towards people with physical and intellectual disabilities. Both groups are vulnerable, although in different ways. People with intellectual handicaps can find their vulnerability increased by physical and psychological effects and would require considerable assistance prior to, during, and after, evacuation. People with physical disabilities will be more vulnerable if hazard effects affect their mobility. Information packs distributed through representative groups emphasises the need for medicines, mobility aids etc. to be held in readiness and to have evacuation routes, and resources, in a state of readiness. Health, social service and support resources in areas where these groups will be relocated are reviewed and strengthened.

By 7 May, when the earthquakes are continuing, many people are concerned and worry about whether to send children to school, and whether to allow them to attend after-school activities in areas that are not close to their homes. Parents who work some distance from the home and the area where their children attend school are especially concerned. Children are particularly sensitive to the anxiety of those around them and schools will be distributing information about typical reactions at this time. Schools note that children may be displaying reaction and anxieties that reflect parental concerns. They reassure children and provide information packs for parents. These packs include information about volcanic eruptions in

general, as well as information about contingency planning and evacuation procedures. This additional source of information helps parents cope and provides a supportive environment for their children. Schools use the recently-developed GIS-based interactive educational tool to assist children to understand what is happening.

By 9-10 May (weekend) people relax a little as they become used to the activity and the situation does not seem to be getting any worse. Informative and accurate media coverage should continue throughout this period to maintain public awareness to prevent complacency. At this time, increased awareness, coupled with relatively lower perceived threat, provides a context for hazard education and leads to higher information uptake and implementation than during the earlier 'high anxiety' phase. This is an appropriate time to provide information on specific preparations and planning for individual, family and community needs. Similarly, information pertinent to the needs of minority groups is collated and distributed to the appropriate group for dissemination. Heightened awareness coupled with low perceived threat results in substantial demands being made for information. Helplines are used heavily during this period. Trained helpline staff are in high demand. Careful selection and their prior training in understanding individual/community needs assists them to provide accurate and consistent information in response to a range of requests and/or to refer caller to more appropriate sources of information

On 13 May the Alert Level is raised to 2. The community becomes anxious again, and many people start to consider stocking up on food supplies. Local supermarkets experience some shortages – mainly in canned goods. Helplines experience higher demands. Encouraging people to act on the information they have been given can help facilitate a sense of control and so reduce some psychological vulnerability.

By 15 May (Day 21) the area of potential explosion is defined as a 3 km diameter area centred on the Queen St/Karangahape Road intersection. People living in this area become seriously worried and many move precious possessions to relatives and friends living further away. Some people with holiday homes move out of the city, and others move to relatives in outer suburbs. Schools practice evacuation procedures and notices are given to parents advising them that schools may close shortly. The university declares a two week break. Emergency services throughout the region prepare plans for moving large numbers of people. Throughout this period and the following weekend, liaison with the media provides information to the public about what is happening and advice on what action to be taking. In consultation with minority liaison representatives, evacuation and logistics plans are implemented, including preparations of sites for re-location of those being evacuated. The public reaction to these evacuation warnings is mixed. Some individuals and families not under direct threat decide to move. Others are fearful, but reluctant to move, particularly

elderly individuals who often perceive the threat of leaving a long-established home or significant personal belongings.

Lava starts to flow down Queen Street and lava fountains, ranging from 100m to a maximum height of 500m, appear. Media coverage of these scenes heightens anxiety throughout the region and is accompanied by information that these phenomena are confined to the immediate vicinity of the eruption and reassurance that those living in outlying areas will not be affected directly. People in areas beyond the immediate impact zone encounter tephra and fine ash fall and see gas clouds. Constant and consistent information about these effects and their implications is required, including public health information to reduce the risk of *ad hoc* evacuation and road congestion. Ash fall and gas clouds represent significant sources of stress for inhabitants. Information about toxicity and keeping ash out of houses is disseminated as well as information for people with babies and small children, or those with respiratory or other health problems who might be affected.

### 6.3.2 The City

By mid May, people who work in the CBD and environs who live in outer areas and are able to work from home are doing so where possible. People working in the city who have children at school are more anxious, and begin to restrict after school and after work activities. From 15 May some city streets are closed at night as tilt levelling sites are surveyed.

On Friday 15 May University lectures are postponed and students given a two week break. Some students decide to go home, but many remain in the city. For overseas students, liaison between counselling services and ethnic group representatives provides information and support services, and opportunities to call home help to allay the concerns of family members overseas. Schools advise parents that closure is imminent.

Over the weekend the site for an eruption is determined within a one kilometre radius. Schools from Point Chevalier, north of Mt Albert and Mt Smart Road, and through Remuera and Orakei as well as many on the North Shore advise parents (using PTA networks) that they will close for an indefinite period.

On Monday 18 and Tuesday 19 May, all residents and businesses remaining within 1km of the likely site are evacuated to outer areas of Auckland. Roads are closed and essential services only remain in the central city area. Police are deployed to prevent looting and to control the activities of sightseers.

### 6.3.3 The Harbour

In April, most Auckland based yachts are in the local marinas and moorings. Since it is shortly before the season for sailing to the islands, there is also a significant number of foreign yachts in the area with crew living aboard.

By 13 May many foreign yachts (including super yachts) have left the area. Other yacht owners decide to move their vessels to other areas such as Whangarei where moorings quickly become full.

In early May shipping is warned, and some coastal shipping diverts to Tauranga. By 15 May when it is evident that an eruption is likely all shipping is diverted to other ports, and companies operating on the wharves begin to implement contingency plans. There is significant increased trucking activity as attempts are made to move containers to the railway yards. Additional trains are used to move containers out of the area and to alternative ports.

### 6.3.4 Business and Commercial Aspects

Two major conferences have been planned for Auckland around this time, one 18-20 May, and the other in early June. By the end of the first week in May the organisers of the first conference (to be held at the Aotea Centre) have prepared contingency plans for the conference. Four thousand overseas visitors are expected and local hotels are concerned about possible loss of custom.

By the middle of the second week in May (when Scientific Alert Level 2 is declared) the conference organisers for the first conference decide to transfer to Christchurch. The second conference (smaller) begins to make contingency plans to move to Rotorua. When Alert Level 2 is declared, businesses are advised to hold their re-location and/or continuity plans in readiness. At this point they recognise that they need to consider not only their immediate operational requirements (facilities), but also their staffing needs and the implications of an eruption for staff availability (e.g. family issues, relocation) and capability. Crisis operational procedures, management systems, and stress management are developed. Human resource continuity plans are prepared for managers and staff.

By 14-15 May when the location has become more defined many businesses move equipment and operations to other areas within Auckland. Few businesses consider moving away from Auckland, but large commercial operations with offices in other centres decide to move some activities on a short term basis. By 17 May some of these large organisations have also moved some staff outside the region. Business continuity plans are implemented and human resource planning issues are addressed.

By 15 May small shops and cafés are affected by the presence of fewer people in the central area. Most restaurants in the city close at night. Hotel custom is down as visitors either decide not to stay in Auckland, or to reduce their length of stay. Tour operators bypass Auckland.

### 6.3.5 The Airport

From 15 May, preparations are made to transfer flights to Wellington and Christchurch in case of ash disrupting the airport. In the event, the wind patterns are such that the airport continues to operate in daylight hours, but once the eruption has begun it closes from 6pm to 6am as a precaution. A light dusting of ash is experienced on 2-3 occasions but does not significantly disrupt flights. Some international flights are transferred to Christchurch and Wellington.

### 6.3.6 Council and CD activities

As soon as Scientific Alert 1 is declared (3rd May) local authorities (CD) and emergency services staff begin to plan for a possible eruption. By 13 May when the level is raised to 2, contingency plans for evacuation are in place and all personnel involved are on alert. From a social vulnerability perspective, Council and CD activity focuses on liaison with community representatives and co-ordinating the resource allocation and distribution to support their activities. This limits the risk of response generated demands complicating response and recovery. Liaison with scientific and specialised information (e.g. gerontological and psychological) and service providers is activated when Scientific Alert Level 1 is declared. Council continuity plans are implemented and accommodate human resource issues.

### 6.3.7 Clean-up

Clean-up is an issue as soon as the eruption commences. Fire service and emergency services are faced with making decisions about where and when to intervene. The first steps are to ensure that no people remain in the area affected by the projectiles or likely to be affected by lava flow. Once this has been accomplished, emergency services liase with GNS staff to attempt to forecast the course of the eruption and to determine what can be done to protect property (if anything).

It is obvious that the central city area will remain uninhabitable for a considerable period of time. About 10% of buildings in the area (bounded by a 750m radius) are destroyed immediately, and another 10% are destroyed by fire. Over the longer term social vulnerability will be influenced by the availability and adequacy of insurance, the extent of loss of valuable and/or significant personal belongings, the period of re-location and the quality of life during this period, options for re-building (e.g. adequacy of insurance, perception of previous and/or new housing location (e.g. sense of security, desirability of alternative housing locations)).

By 30 May lava flow has ceased. Sporadic eruptions are continuing, but it is considered to be safe to begin cleaning up the areas adjacent to Queen St that are not overrun by lava. Buildings are inspected for structural activity – a process that continues for several months. Roads are reviewed and arterial routes repaired to allow emergency and cleaning services access. Removing debris from damaged and destroyed structures is well underway. Traffic is restricted to essential vehicles and cleanup crews only for the first four weeks.

By mid June a number of businesses are preparing to return. Several tourist-oriented businesses, catering for foreign and domestic trade, focusing on tourism and activities related to the volcanic field and the effects of the eruption. A sound media management plan which ensured that accurate information was disseminated, including television coverage of the limited extent of damage and the effectiveness of the response and recovery operations, supported this aspect of recovery.

The port area has suffered considerable damage, but the harbour itself has not been significantly affected. The area around Tasman Wharf is able to be cleared reasonably quickly and operations begin there within one month of the eruption (mid June). Priority is given to clearing and repairing the adjacent wharves and the railway yard areas (mainly ash damage) to allow some shipping to be resumed. Early shipments include building materials and equipment.

The airport has suffered minimal disruption.

No schools have suffered major structural damage, but all are inspected before classes are allowed to return. Ash removal is undertaken by a mix of Council and volunteer operations.

The university has suffered considerable structural damage and classes are unable to resume on the city campus until the following year. Classes are transferred to Tamaki campus and assistance is given by Albany (Massey) and AUT.

## 7.0 POLICY DEVELOPMENT AND EVALUATION

### 7.1 All-hazards Approach

While it would be necessary to determine the effects and parameters for each physical hazard (e.g. volcanic eruptions, earthquakes, tsunami, cyclone, etc.), social vulnerability indices are relatively robust with respect to their implications across hazards. Vulnerability assessment models can thus be used, with some qualification, to estimate vulnerability to a range of hazards. Further work needs to be done to determine the weightings applied to vulnerability factors and whether these weightings apply across hazards or whether they change with different hazards.

Qualification includes considering the meaning attributed to different hazards and their relative salience. For example, while the tangible hazard is represented by the eruption and its effects, perceived salience can equally reflect concerns about economic implications, threat to future security etc. Consequently, threat communication must be adapted to suit the relationship between hazard characteristics and salient community concerns. It will be necessary to research the relationship between physical effects and social vulnerability. For example, to compare the perceived threat of volcanic ash entering the water supply with that associated with inundation of sea water following a tsunami. Research is needed to examine whether hazards influence social vulnerability quantitatively or qualitatively. If the former prevails, social vulnerability models will be suitable for use in an all-hazards model. If qualitative differences are found, it will be necessary to develop contingent social vulnerability models.

When considering the general applicability of vulnerability data, a distinction can be drawn between natural and human-made/technological hazards. While their impact, in terms of geographical destruction and actual, or potential, loss of life, tends to be greater, the psychosocial impact of natural disaster may be relatively less pronounced, generally because they are perceived as unavoidable "acts of God". Human-made/technological events often generate a relatively more substantial psychosocial impact because this class of event is perceived as being more preventable. Perceived and attributed responsibility, and heightened feelings of loss of control increase vulnerability to this class of hazard. This should not be taken to imply that the characteristics central to this report cannot be used to define vulnerability to technological hazards. Rather, their use must be qualified by a knowledge of the nature of the interaction between people and hazard consequences.

## 7.2 Policy Recommendations

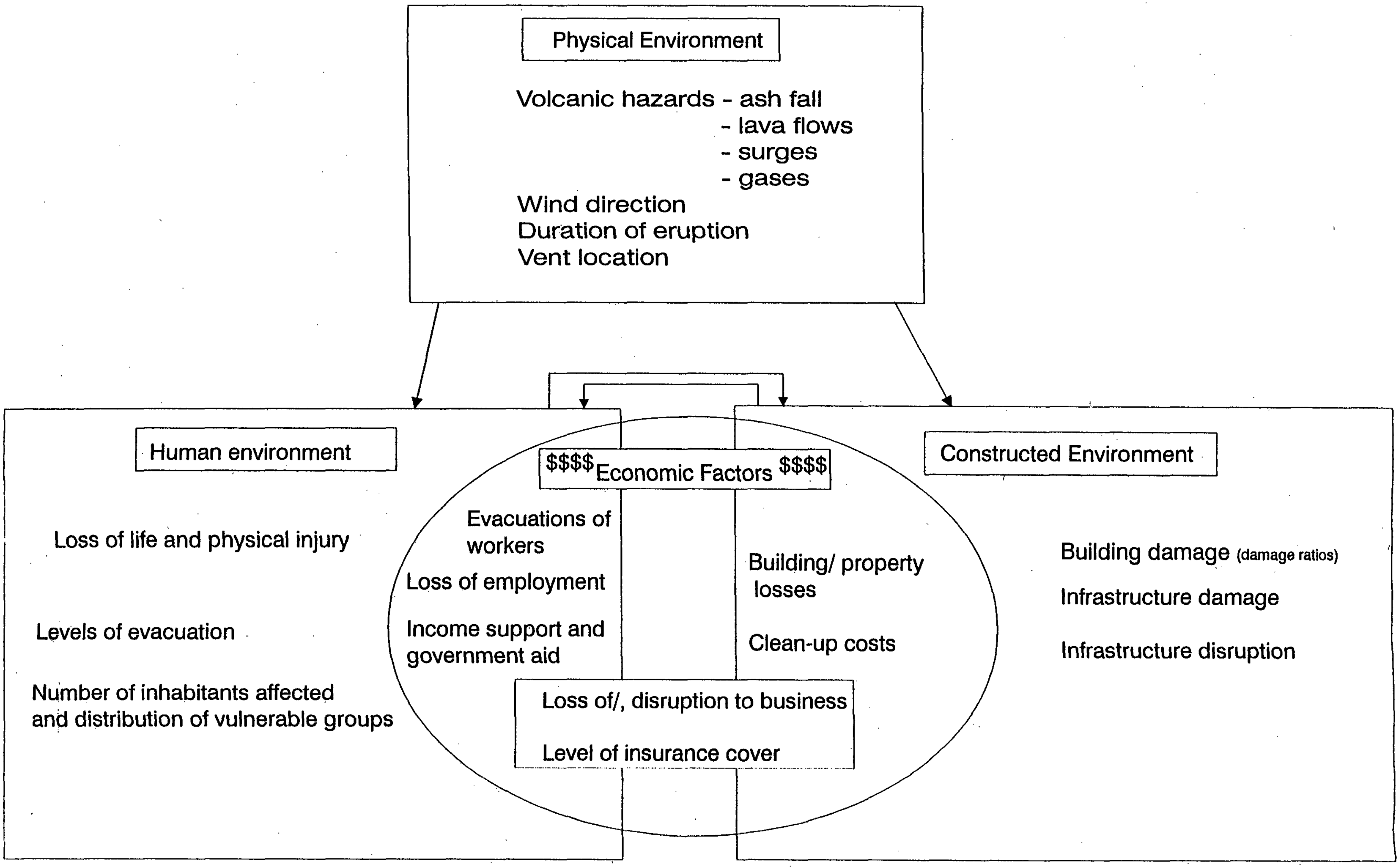
This report discussed several factors (e.g. patterns of interaction between physical and social vulnerability, number and distribution of vulnerable groups) necessary to understand the nature and complexity of Auckland's vulnerability environment. Key factors are summarised in a model of volcanic risk shown in Figure 13. The complexity of this environment, coupled with limitations in the knowledge base regarding causal relationships between these factors and key mitigation activities (e.g. design of hazard communication and education programmes for diverse groups) necessitates the development of strategic emergency management plans that link reduction, readiness, response and recovery planning with a systematic programme of research and analysis designed to examine these issues within a New Zealand context.

An important element in this strategic planning will be the development of liaison mechanisms with research/scientific organisations and community agencies representing groups identified as vulnerable. These liaison mechanisms can be used to develop training and educational programmes specific to the needs of each group, provide an input to the training process of Regional and other staff, and provide an input into the development of information management systems to support planning and response management. Liaison and collaboration will also help researchers and Council staff develop a more integrated working context that will increase the quality of the research and intervention process.

The complexity of the vulnerability environment, both with respect to the number and distribution of vulnerable groups and the patterns of interaction between physical and social factors, emphasises the need for contingency planning and analysis linked to the research process (e.g. analysis of hazard-vulnerability interaction, meaning attributed to hazards, hazard effects and mitigation strategies, content and medium for information dissemination, identification and management of community resilience characteristics, etc.).

Further work is necessary to develop a comprehensive database for social vulnerability analysis. At present, because it has not been collected for this express purpose, the data available is incomplete. A dedicated database is needed to support planning and to facilitate more comprehensive modelling of processes that, for example, threat communication and preparedness programmes are designed to ameliorate (including comprehensive process, content and performance evaluation). This is particularly relevant for planning programmes designed to enhance community preparedness and resilience.

# MODEL OF VOLCANIC RISK IN AUCKLAND



Analysis of the number and distribution of vulnerability groups revealed a complex vulnerability environment. This diversity has significant implications for understanding hazard perception and designing threat communication programmes, including analysis of the relative salience of hazard versus other threat and concerns (e.g. economic, social welfare and crime issues). If this state of affairs prevails, differences in relative salience imply the need for hazard information to be incorporated into other community development initiatives rather than being tackled independently. This has implications for future research and for intervention development.

Several response issues should be considered within the strategic review. These include, for example, mobilising community groups and planning evacuation (including liaison with group representatives, planning areas and resources for location and, if necessary, re-settlement). Liaison will be required to ensure that support needs relating to, for example, family status, age, cultural, religious and spiritual needs are accommodated. Similarly, the analysis of community functions and needs should be conducted within the strategic process and should be linked to plans designed to foster community resilience (with respect to both the built and the psychological environment) and to ensure that community resources are accommodated in planning, response and recovery initiatives.

While several of the above policy recommendations lie outside the scope of the current project (e.g. the development of liaison mechanisms, causal modelling, information management and communication systems), this report provides a basis for planning the realisation of these objectives. At a practical level, this would include, for example, research into the development of vulnerability indicators and weightings, and the development of a parsimonious set of indicators to assist strategic and operational planning, the identification, allocation and distribution of resources; vulnerability/risk scenario modelling; plan development and testing; and process, content and performance evaluation of plans, simulations and systems.

An important future activity will be the identification of key indicators. These are difficult to specify at present given the fact that existing databases have not been developed to support emergency planning.

### 7.3 Interactive Education Tool

The availability of a variety of digital data sets allows for the development of innovative ways of using the world-wide-web (Internet) to educate the public about the potential impact of hazards. By linking data sets with an appropriate web-based interface, users can superimpose various layers to explore relationships between the physical and social elements that create vulnerability. This project has identified a number of issues that need to be resolved before a

truly interactive web site can be developed, such as data licensing, cost and web-site hosting. However, a simple web-site can be developed in which certain pre-determined layers are installed and users can access these by selecting a number of options. Suggested layers relevant to this study include:

- all scenario points and polygons (vents, tephra distributions)
- generalised distributions from census data
- 'deprivation' zones, not from Index of Deprivation but 'hotspots' that were taken into account with Douglas Paton's work
- low income areas
- vehicle ownership
- age groups

These can be supported by appropriate explanatory texts that guide the user through the issues that have been identified in this study. These outputs can be used for school education, community group education, ethnic group education, and training/education of emergency managers, response agency staff and others.

## 7.4 Summary and Future Directions

**Vulnerability Analysis**

A three-tiered model of vulnerability, comprising demographic, community, and individual/psychological level variables was developed in the preliminary stages of this project to describe the diversity of factors that influence social vulnerability to hazard consequences.

From this initial framework, parameters were selected for the vulnerability analysis on the grounds that:

- they represent fundamental units of vulnerability;
- the selected variables could be easily measured and applied directly within a GIS model; and
- the variables selected would be relatively constant over the time frame of the project and beyond, allowing the product of this research to be used in the development of policy and planning initiatives.

In the context of the above criteria, demographic variables were selected for this preliminary analysis because:

- demographic factors are readily measurable over time;
- demographic data were readily available from existing and recent databases, and could be used directly;

- the tangible nature of demographic vulnerability data renders it particularly appropriate for planning and policy development;
- demographic data can be used in a GIS model without making any assumptions or inferences about the data; and
- demographic variables are less affected by short term variation, rendering them more appropriate as a starting point for hazard management, policy and planning initiatives.

Demographic variables were selected for this analysis and the development of a GIS model of social vulnerability. The demographic variables included were: socio-economic status (assessed using scores of 6 and over from the Deprivation Index); age and ethnicity (using Census data).

However, a comprehensive model of social vulnerability cannot be constructed using demographic variables alone. Vulnerability will fluctuate (increase or decrease) as demographic factors interact with community, social psychological, organisational and environmental vulnerability variables. The sensitivity of the GIS model described here will be affected by the way in which each of these factors interacts with factors modelled here. Inferences regarding community vulnerability made on the basis of these data, and any models derived therefrom, should accommodate this constraint.

It is not possible, at this stage, to increase the usefulness of the model by including a comprehensive range of vulnerability variables. The lack of databases capable of furnishing data on the latter variables precludes their inclusion in the model at this stage.

While these other variables do affect vulnerability, their role in this capacity within the Auckland Region can only be inferred, until they are systematically defined and assessed.

Future development of the Auckland Regional Council vulnerability analysis model will require the collection of relevant data from community surveys, and other mechanisms used to gather community-wide data.

**Vulnerability Environment**

The GIS model indicated a complex vulnerability environment. This conclusion was based on the highly dispersed nature of the distribution of vulnerable group membership throughout the Region.

Highly dispersed populations make the development and implementation of threat communication and reduction strategies highly complex. Mass communication approaches, or area-wide strategies, become less effective because of the difficulty of designing messages

and action plans that accommodate the diversity of needs, goals and expectations that reflect group differences within a specific geographical area.

To resolve this issue, it is proposed that, where possible, vulnerable groups be targeted directly. It is possible to begin the process of realising this strategy using existing resources.

Existing social policy agencies have an in-depth knowledge of, and communications links with, groups identified here as being vulnerable to volcanic hazard effects. The existing practices and procedures of social policy agencies may provide an appropriate basis for managing demographic vulnerability over the long term within natural hazard reduction programmes. Currently social policy agencies in Auckland are working towards a more integrated, holistic approach (e.g. "Strengthening Families"). However, additional work is required to develop this capability. Several issues must be addressed.

The atypical nature of volcanic hazard effects and the diversity of their implications for different demographic groups suggests that care must be taken with respect to assuming that vulnerability to natural hazard effects reflects vulnerability to other social risks. Additional work is required to assess this issue.

Limitations on the availability of relevant data resulted in this project concentrating on demographic variables (see above for rationale). The selection of demographic variables for the vulnerability model facilitates existing social policy agencies playing a role in hazard management initiatives. The capabilities of existing social policy agencies to manage vulnerability should be considered in this context; specifically, they represent a resource that could be used to manage demographic vulnerability. This strategy would not provide for the comprehensive management of vulnerability.

It is important not to assume that the policies and practices used by social policy agencies can automatically be applied to social vulnerability and resilience assessment. Existing policies and procedures should be examined with respect to their applicability.

The systems and procedures established to assess and manage vulnerability must be capable of responding to hazard-related issues and with the changes in vulnerability that can be anticipated over time. This issue is of particular importance when using vulnerability analysis to direct response management initiatives.

If a decision is made to use established social policy agencies to define and deal with vulnerability, attention should be directed to their resourcing, the development of the requisite infrastructure, policies and procedures to assess and manage all facets of vulnerability (not just those emanating from demographic diversity) and changes therein over time, the

development of the knowledge, systems and procedures required to deal with issues that will change over time, and the provision of specialist training in the application of their expertise to the management of vulnerability to natural hazard effects.

Existing operating policies and procedures may be less appropriate for the management of resilience. Resilience is not the opposite of vulnerability. Reducing vulnerability does not automatically lead to increased resilience. Additional work is required to develop this capability (see below).

Taking on board these provisos, existing social policy agencies could be used to elicit perceptions of hazards and their consequences and implications for the demographic vulnerability categories identified here. These agencies could also act as mechanisms for the articulation and implementation of reduction, readiness, response and recovery plans for these groups.

With respect to natural hazard reduction and readiness initiatives, vulnerability analysis can be used to: underpin long-term policy and strategy development with the objective of reducing community vulnerability; articulating group needs and perceptions; planning educational and mitigation programmes accordingly; and ensuring their delivery in a manner appropriate for the needs of each group.

With respect to response management, GIS-based vulnerability analysis could provide social policy agencies with information that can be used to plan the deployment of scarce resources and to guide the provision of appropriate information and services to groups or areas where need is greatest.

With respect to recovery management, GIS-based vulnerability analysis could provide social policy agencies with data with which to plan the provision of resources and information required by vulnerable groups, or providing the mix of information and resources required within specific areas, to facilitate group or community-led recovery and rebuilding.

From the perspective of promoting community resilience as a key policy goal, the limitations of a vulnerability-based approach must be recognised.

Practical and conceptual limitations are imposed on the use of vulnerability as policy and practical device.

The usefulness of vulnerability analysis is constrained by the number of vulnerability factors that have been identified and the existing difficulties in assessing them and incorporating them into policy and planning initiatives.

The usefulness of vulnerability analysis is constrained by interaction effects. For example, vulnerability from membership of a particular demographic group may increase or decrease depending on the manner in which it interacts with other vulnerability variables.

The usefulness of vulnerability analysis is constrained by the fact that some variables can act as vulnerability factors under some circumstances and as resilience resources under others (this applies to the demographic characteristics that constituted the basis of the present analysis). This point reiterates the complex contingent analyses that are required for effective vulnerability management. For example, vulnerability generally increases with age. If individuals' life experience allows them to deal with adversity, older people can become more resilient. This pattern was noted in Ohakune following the 1995/96 Ruapehu eruption.

**Community Resilience**

While vulnerability analysis and management must remain on the long term policy and planning agenda, alternative approaches to community natural hazard assessment and management are required. One alternative is to adopt a mix of community-based strategies that focus on integrating development/empowerment and resilience.

Initial work on resilience models suggests that they represent a more robust (e.g. within all-hazards framework) and concise model of natural hazard management, and one which is less sensitive to the kinds of interaction effects that limit the utility of vulnerability models.

The adoption of the resilience approach could be developed within existing policy and management frameworks. It would require attention being given to several issues.

The adoption of resilience as a policy goal has implications for the nature of the relationship between social policy agencies and community groups. Specifically it involves a shift in the relationship between agency and community to focus on the facilitation of community self-help and self-reliance rather than on the provision of services to a community.

The rarity of natural hazard consequences requires that resilience programmes be integrated with community development and empowerment programmes that facilitate the ability of communities to articulate and manage the problems they define as being of particular importance to them.

This strategy can be expanded to encompass natural hazard management issues by, for example, providing groups with hazard scenarios that serve as a basis for them to articulate the needs they perceive in relation to these scenarios and the resources required to resolve or contain them.

The role of social policy agencies in this context is to facilitate discussion, collate the similarities and differences in perceptions and needs, feed these data back into the emergency management process, and arrange for the distribution of resources to community groups.

The development of a resilience programme will require a review of policy agency resourcing and the development of the requisite infrastructure, policies and procedures to assess and manage resilience and community empowerment.

The realisation of these objectives will require the provision of specialist training in the management of resilience and community empowerment and the establishment of an infrastructure appropriate to sustaining resilience initiatives.

Models of community resilience, developed to accommodate the implications of hazard management within an all-hazards framework, exist. Developing management capability requires that data on the elements of the model be collected. This requires that surveys undertaken by, or on behalf of, ARC should be reviewed with respect to possibilities for using their data to develop and test the resilience model.

**Summary**

The demographic vulnerability analysis conducted here, and its incorporation into a GIS model that can be used as a planning and response management tool, provides a strong foundation for the future natural hazard management within the Auckland Region. The limitations of this model, both with respect to its orientation and its ability to capture and model all relevant vulnerability data, signals the need for the development of a long term approach to the development of natural hazard management capability. The analysis and management of social vulnerability should remain as a key policy goal within this process. It should be supplemented by the adoption of a resilience-based assessment and management strategy that focuses on the integration of hazard management and community empowerment within a model that seeks to promote community development and growth.

## 8.0 RECOMMENDATIONS

- Valuation data is still required in order to complete the loss model. Further work is required to gather appropriate data in a form that can be integrated with the GIS system.

- A key determinant of the economic effects of such events is their impact on insurance markets. Currently it is very difficult to establish the extent of insurance cover from the various insurers, in various locations. More work is required to determine the "true" level of insurance cover in Auckland. One risk with the onset of a volcanic crisis is that it may lead to changes in premiums or the cancellation of policies. This also needs to be investigated.

- Development of the vulnerability model will require the collection of relevant data from census and community surveys and other methods for gathering community-wide data, as a comprehensive model of social vulnerability cannot be constructed using demographic variables alone.

- Models of individual (e.g., adjustment adoption) and community (e.g., empowerment) resilience should be developed separately from vulnerability models. Vulnerability can be used to support social policy intervention. Resilience models can be used to promote the adoption of risk reducing behaviour, community empowerment, and the development of institutional frameworks to link them.

- A review of policy agency resourcing and the development of the requisite infrastructure, policies and procedures to assess and manage resilience and community empowerment is required.

- Specialist training for council staff in the management of resilience and community empowerment is also required to develop an effective programme.

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