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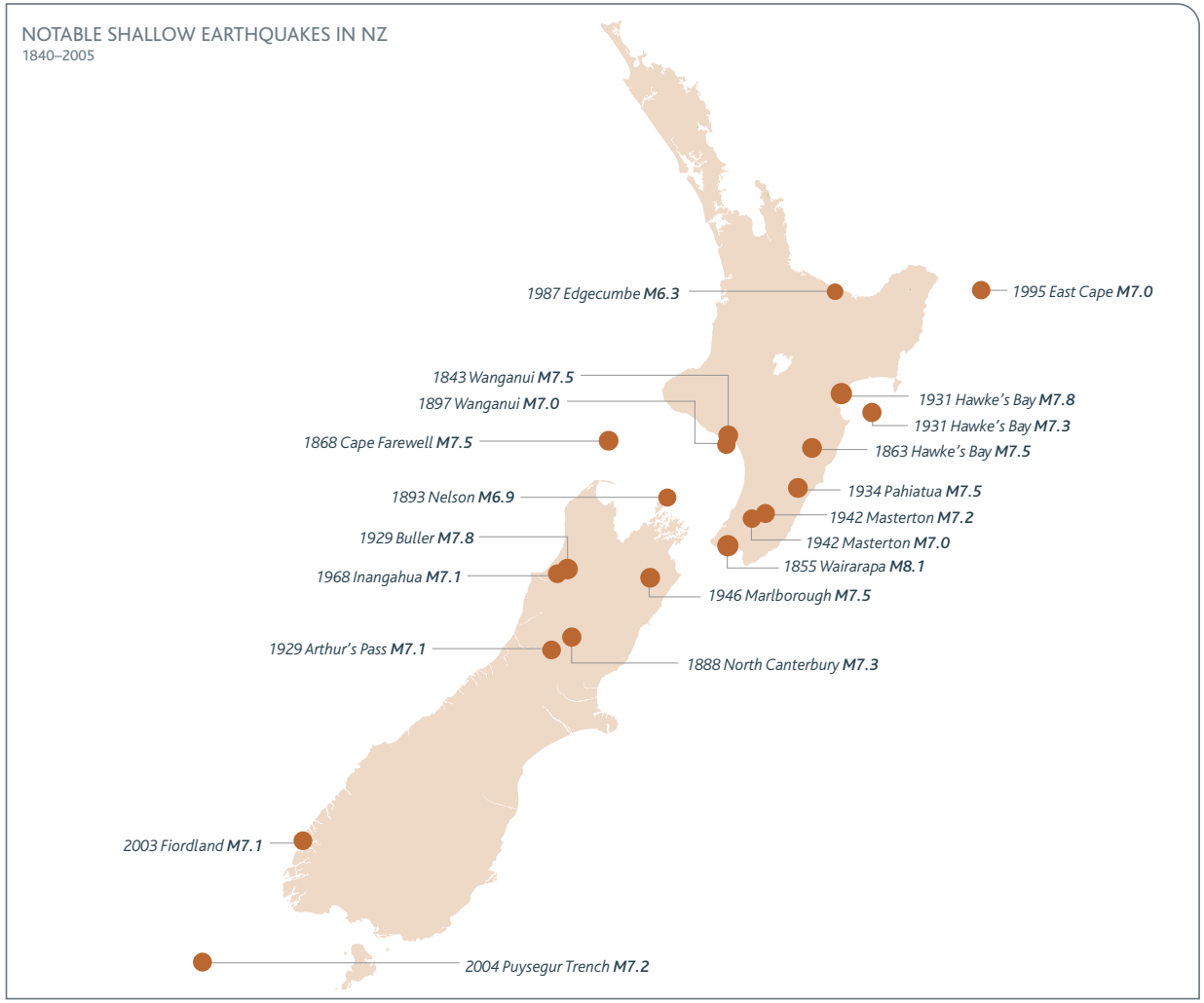
NEW ZEALAND HAZARDSCAPE

EARTHQUAKES

New Zealand experiences many earthquakes because it is located across the boundary of two tectonic plates. Ten to fifteen thousand earthquakes are recorded each year in and around New Zealand, but only about 150 of these are felt.

Based on its seismic history, New Zealand should experience 10 to 20 magnitude 5 earthquakes and one magnitude 6 earthquake each year, and a magnitude 7 earthquake each decade. However, earthquakes are not evenly spread over time and they often occur in clusters. The last 60 years have been relatively quiet with only two onshore earthquakes greater than magnitude 7. But a damaging earthquake could happen at any time. At least a million New Zealanders (around 25 per cent of the population) are expected to experience shaking great enough to damage household contents and buildings in the next 50 years.

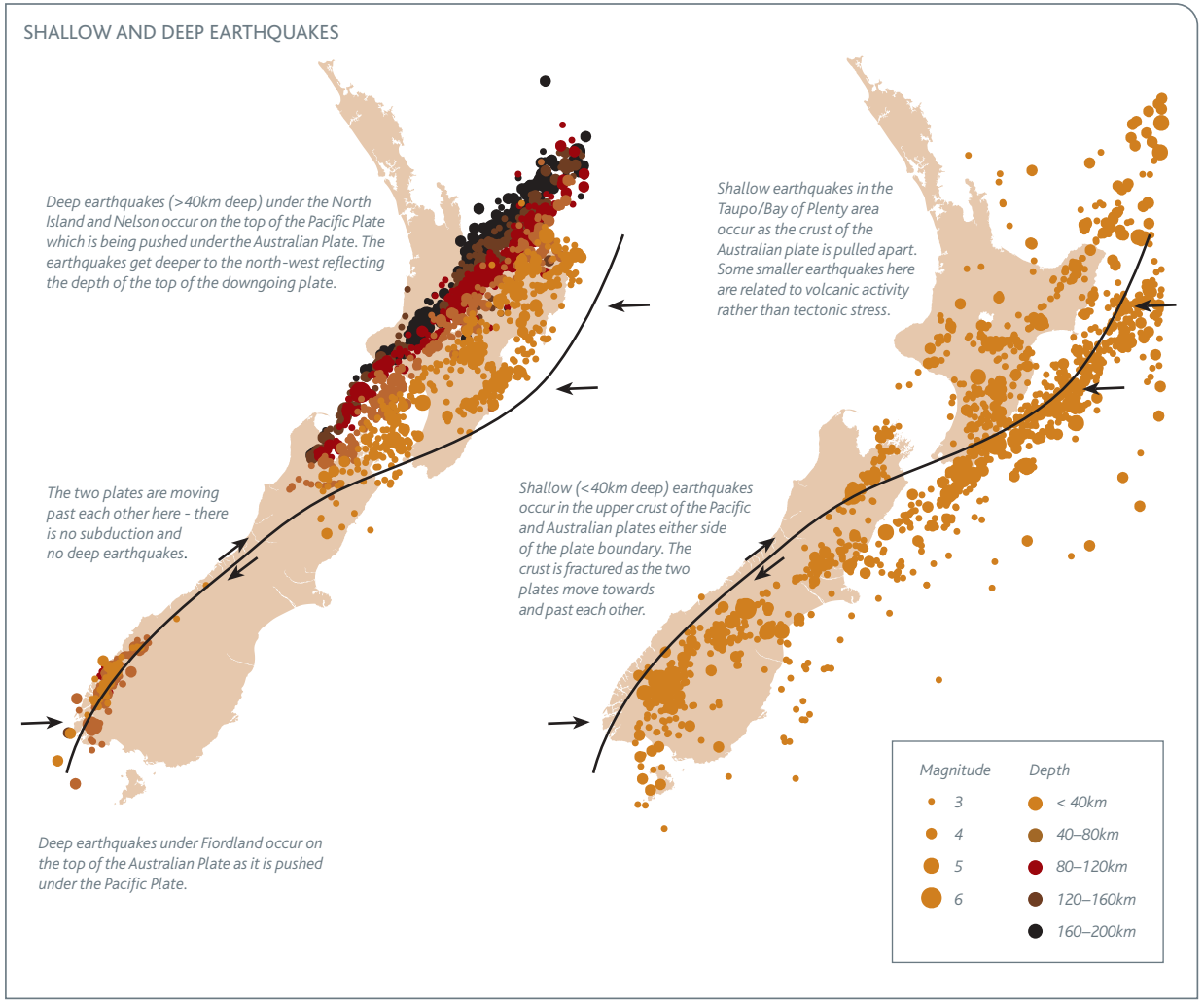


Major historic earthquakes in New Zealand since 1840. Many damaging earthquakes occurred in the early years of European settlement but there have been few over the last 60 years. *GNS Science*.

New Zealand's earthquakes

An earthquake is the sudden release of slowly built-up strain along a fault (fracture) in the earth's crust. In New Zealand that strain accumulates as the Pacific and Australian tectonic plates move past each other. Most of New Zealand's seismic activity, including its major historic earthquakes, occur within a broad zone of deformation about 100km wide that runs along the plate boundary from offshore East Cape to Fiordland.

High-hazard areas along this zone include Gisborne, Hawke's Bay, Wairarapa, Wellington, Marlborough, North Canterbury, Buller, the Southern Alps, and Fiordland. The earthquake hazard in these areas is comparable to that in California. Northland and southeastern Otago, farthest from the plate boundary, have the lowest earthquake hazard. Moderate but damaging earthquakes have however occurred in both these locations.



Earthquakes of magnitude 2 or greater recorded in New Zealand in 2005. The distribution and depth of earthquakes is related to the behaviour of the two tectonic plates. *GNS Science*.

The earthquake hazard in New Zealand represented as the intensity of ground-shaking expected in a 50-year period, based on historical seismicity and the location of active faults in New Zealand and how frequently they move. *GNS Science*.

EARTHQUAKE MAGNITUDE AND INTENSITY

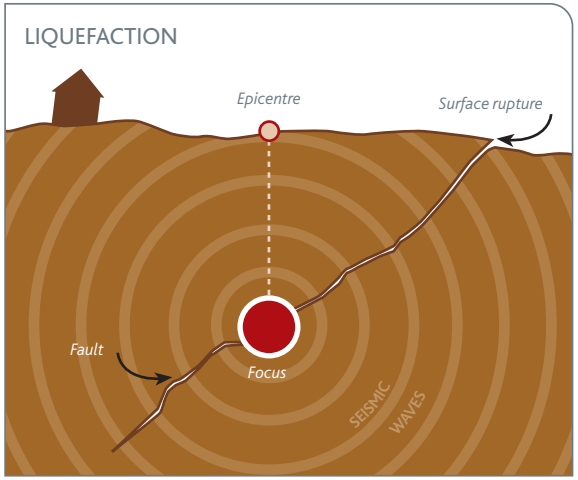
Earthquakes are described by both their magnitude and their intensity. Earthquake magnitude is a measure of the energy released during an earthquake, or its 'size'. Charles Richter first devised a magnitude scale in 1935 using data recorded on seismographs.

Earthquake intensity describes how much ground shaking occurred, or how 'strong' the earthquake was, at a particular location. Earthquake intensity depends not only on the magnitude of the earthquake but also on how far away it was, how deep it was, and the local geology, for example whether the ground is sand or rock. An earthquake generally feels less intense further away from the epicentre. In New Zealand intensity is measured using the Modified Mercalli (MM) intensity scale which is a descriptive scale from 1 to 12 based on how people feel an earthquake, and the damage to contents and buildings.

Shaking below MM intensity 4 is generally not felt or only felt inside. With MM intensity 7 shaking, it is difficult to stand, furniture breaks and loose bricks and tiles fall. Intensity 8 shaking damages ordinary masonry and topples chimneys and towers. Intensity 9 shaking causes panic and damages or destroys masonry and foundations. Damage is almost total with shaking at MM intensity 12.

Earthquake hazards

The energy released in an earthquake, and the permanent ground deformation produced, creates earthquake hazards with a range of both local and widespread impacts.



Earthquakes generated on faults in the earth's crust can cause fault rupture, ground shaking and liquefaction at the ground surface.

Ground-shaking

The energy released during an earthquake radiates away from the earthquake source as a variety of wave types. The intensity of ground-shaking at a particular point depends not only on the magnitude of the earthquake but also on the distance from the earthquake and the local geology. Soft ground, such as sandy or silty sediments, tends to amplify ground-shaking. Aftershocks will also occur after a large earthquake as the land adjusts to the displacement that has occurred.

1931 HAWKE'S BAY EARTHQUAKE

New Zealand's most destructive earthquake happened on the morning of 3 February 1931. A magnitude 7.8 earthquake centred 25km northeast of Napier was felt from Auckland to Canterbury.

Many of Napier's and Hastings' masonry buildings collapsed, including the new nurses' home, killing staff and sleeping nurses. The technical college also collapsed but, as it was morning tea time, most students were outside. In total 256 people died in Napier, Hastings, and Wairoa, and thousands were injured. About 3500 hectares of land, formerly the Ahuriri Lagoon north of Napier, was uplifted almost 2m. A lack of water and sewerage hampered recovery, as did aftershocks including a magnitude 7.3 earthquake 10 days after the main shock. The earthquake highlighted the need for stronger buildings and prompted the development of New Zealand's building standards.

Much of Napier's central business district was destroyed in the 1931 earthquake - many buildings collapsed and were subsequently gutted by the fire that burnt for two days. *Hawke's Bay Museum and Art Gallery.*

These smaller earthquakes can continue for weeks, months, or even years after a large earthquake.

Ground-shaking during an earthquake is inevitable and can be regionally extensive, but buildings and other structures can be sited and constructed in ways that reduce the likelihood of damage and injury.

Fault rupture

If an earthquake is large and shallow (generally greater than magnitude 6.5 and less than 40km deep) the displacement on the fault may reach the ground surface, offsetting the ground both horizontally and vertically. New Zealand has many active faults within the plate boundary deformation zone that have ruptured the ground surface in this way. The largest historic fault displacement was recorded on the Wairarapa Fault, which moved 18m horizontally in the 1855 Wairarapa earthquake. Some faults move more often than others – there are more than 50 faults in New Zealand that, on average, move every 2000 years or less. The most active faults, the Alpine Fault and the Hope Fault in the South Island, move on average every few hundred years, creating large earthquakes and metres of permanent displacement along the fault.

Fault rupture will sever underground services, such as water pipes, that cross the fault, and can damage or destroy structures built on the fault. Fault-rupture hazard is confined to a relatively narrow corridor along the fault, and because fault rupture tends to generally occur repeatedly in the same place, the location of future ground rupture can be predicted with some degree of confidence.

Surface rupture of the Edgecumbe Fault in the 1987 Edgecumbe earthquake, New Zealand's most damaging earthquake in the last 35 years. The ground surface was vertically displaced across several fault strands by a total of 2.5 metres. *GNS Science*.

Liquefaction

Liquefaction occurs when saturated fine-grained sediments, such as sand and silt, behave more like a liquid than a solid during an earthquake. During intense ground shaking (greater than MM intensity 7) these sediments can lose their strength, and buildings may sink or tilt. Buried services such as pipes can become buoyant and rise to the surface, and unsupported or poorly-supported land such as riverbanks and wharves can spread sideways.

A road after the 1931 Hawke's Bay earthquake. Liquefaction of soil under the road caused it to subside. *Hawke's Bay Museum and Art Gallery.*

Areas that may be susceptible to liquefaction can often be identified by their geology. Important facilities can be sited away from these areas, or the soil can be treated by compaction or other engineering techniques to reduce the potential for liquefaction.

Landslides and tsunamis

Landslides are second only to building collapses as causes of death in New Zealand earthquakes, claiming 16 lives in the 1929 Murchison earthquake and three in the 1968 Inangahua earthquake. Large earthquakes can cause widespread landsliding, particularly in the steep and fractured Southern Alps.

Tsunamis can be generated when earthquakes occur off the New Zealand coast, either by rupture of the sea floor or through underwater landslides. Tsunamis triggered by local earthquakes may reach the shore within minutes.

Coastal areas may be inundated due to uplift or subsidence of land during an earthquake. For example, parts of Lambton Quay in Wellington were temporarily flooded immediately after the 1855 Wairarapa earthquake. This was because land west of the Wairarapa Fault was raised, causing water to 'slosh' back and forth across the harbour.

Landslides and tsunamis are also caused by other mechanisms. The consequences of landslides and tsunamis, whatever the cause, can be catastrophic and they are discussed in further sections of this report.

Managing earthquake hazards

Earthquakes happen with little or no warning. Hazard and emergency management for earthquakes relies on risk reduction and planning for response and recovery at an individual and organisational level.

Research by the Institute of Geological and Nuclear Sciences (GNS Science), National Institute of Water and Atmospheric Research (NIWA), universities, and many private consultancies contribute to earthquake hazard management in New Zealand. Research ranges from paleoseismology – determining when prehistoric earthquakes have happened – through to geodesy – measuring how much New Zealand is being deformed on either side of the plate boundary.

Risk reduction

BUILDING DESIGN AND CONSTRUCTION

Building collapses account for the majority of earthquake deaths worldwide. New Zealand, however, is a world leader in earthquake engineering and has a resilient housing stock and high building standards. Most residential buildings in New Zealand are one- or two-storey houses with light timber frames and timber cladding. European settlers realised after the 1848 Marlborough and 1855 Wairarapa earthquakes that wooden buildings withstood earthquake shaking much better than unreinforced brick or stone buildings.

The first earthquake loading standard for buildings, intended to improve lateral strength, was introduced in 1935 in response to damage from the 1931 Hawke's Bay earthquake. The standard was updated in 1965, 1976, 1984, 1992, and 2004. Today's building code aims to avoid structural damage in a moderate earthquake, and to prevent collapse and protect life in a major earthquake. Previous building codes only applied to new buildings but recent changes in the Building Act 2004 apply standards retrospectively to older buildings, which must now be strengthened.

A significant number of vulnerable early concrete and steel buildings, and unreinforced masonry buildings, still exist. Many road and rail bridges were also constructed before modern earthquake codes, and with limited hydrological information.

Lead rubber bearings (base isolators), invented in New Zealand, have been fitted in many buildings both in New Zealand and overseas. These steel-covered blocks of rubber with a lead core isolate the building from its foundations and absorb earthquake energy, helping to protect the building and its contents from ground-shaking damage.

LAND-USE PLANNING

While widespread ground-shaking during a large earthquake is inevitable, some earthquake hazards can be avoided. However, land use planning has, until recently, placed little or no emphasis on earthquake hazards with regard to either the location or the intensity of development.

Areas of soft sediments, which may amplify ground shaking or liquefy in an earthquake and zones where fault rupture may occur are being mapped. This information is used to inform land-use planning at local and regional level. Land-use planning policies are generally not designed to prohibit development in identified high earthquake-hazard areas, but rather to control the type of development. For example, some district plans restrict or place conditions on developing high-rise or important community buildings, such as hospitals, in areas of liquefaction potential, while still allowing lower-risk residential housing.

This approach is advocated in Ministry for the Environment guidelines produced in 2004 for development on or close to active faults, which have been adopted by several territorial authorities in New Zealand. These guidelines promote a risk-based approach to controlling development on or near active faults, based on the fault's activity and complexity and the type of building proposed.

Fault-avoidance zones delineated around the active Ohariu Fault in Kapiti Coast District. The width of the zones depend on how well the location of the fault can be determined. Fault-avoidance zones have been incorporated into several district plans around New Zealand so that development on or near active faults can be managed. *Greater Wellington Regional Council.*

THE NEXT ALPINE FAULT EARTHQUAKE

The South Island's Alpine Fault marks the boundary between the Australian and Pacific tectonic plates through the South Island and forms the western margin of the Southern Alps. The Alpine Fault has not moved since European settlement of New Zealand, but geologists believe it is capable of producing magnitude 8 earthquakes involving many metres of fault movement at the ground surface. Evidence suggests that the last earthquake on the fault, involving surface rupture along almost 400km of the fault, occurred in 1717 AD. Previous earthquakes have been dated at approximately 1630, 1460 and 1220 AD.

Probability estimates for the next Alpine Fault earthquake vary, but are as high as or higher than for any other fault in New Zealand. Most scientists agree that given the current rate of stress accumulating along the Alpine Fault, a large earthquake is very likely within the next 100 years.

The next Alpine Fault earthquake will cause major damage across the South Island. Transport routes will be impassable with bridges damaged and landslides blocking roads and railway lines. Electricity supply will be disrupted in large parts of the South Island. If the earthquake occurs in summer, many tourists will be isolated on the West Coast. International assistance is likely to be required and many aftershocks will affect response and recovery.

Earthquake-induced landslides in the Southern Alps will also feed large amounts of sediment into rivers, which will slowly work its way down valleys and onto the coastal plains. This is likely to produce erratic river behaviour including major changes of course and flooding, particularly on the West Coast lowlands, for years after the earthquake.

The South Island looking north along the Alpine Fault, one of the most significant onshore faults on earth. The fault has displaced rocks in Nelson and Fiordland that were once adjacent by 480km and has created the Southern Alps. *Image Science and Analysis Laboratory, NASA Johnson Space Center, image ISS006-E-39504.*

WELLINGTON EARTHQUAKES

The Wellington region was the scene of New Zealand's largest historic earthquake – the magnitude 8+ 1855 Wairarapa earthquake. Occurring on the evening of 23 January, the earthquake was accompanied by surface rupture along 140km of the Wairarapa Fault on the eastern margin of the Tararua Range. The earthquake also caused up to 6m of uplift to the west of the Wairarapa Fault, triggered landslides across 20 000km^2 of land, and generated a tsunami that measured 9m in Palliser Bay and 2–3m in Wellington Harbour.

The population of Wellington at the time was only around 6000, and the mostly timber framed buildings sustained little damage. It had become apparent after the 1848 Marlborough earthquake seven years earlier that timber buildings were the best construction for earthquake resistance. However, almost all the chimneys in Wellington fell down – one killing a hotelier – and there was severe damage to brick buildings. Up to six more people were killed in the Wairarapa when a whare collapsed.

The Wairarapa Fault is one of several active faults under the Wellington region. The residents of Wellington in 1855, who had recently moved there from the flood-prone Hutt Valley, didn't realise that they had settled over the active Wellington Fault. One hundred and fifty years later, Wellington is the nation's capital and the Wellington metropolitan area is home to 375 000 people. An earthquake on this fault today would cause around 3000–4000 casualties, including between 200 and 600 deaths (depending on the time of day), and cause more than $10 billion worth of direct damage. The Wellington Fault is thought to rupture, producing a major earthquake, every 500–800 years; it last ruptured about 400 years ago.

The active Wellington Fault, capable of generating a magnitude 7.6 earthquake, runs from the Wellington south coast, through Karori Reservoir and Thorndon and north along the western side of Wellington Harbour and the Hutt Valley. *GNS Science*.

Readiness

The ability to monitor earthquake location and size is improving but scientists still cannot predict when and where a damaging earthquake will occur. Some major earthquakes, such as the 1929 Murchison, 1888 North Canterbury and 1987 Edgecumbe earthquakes, were preceded by many small tremors, but most of New Zealand's damaging earthquakes have occurred with no warning. However, high quality, near real-time earthquake information, provided by the EQC funded national geological hazard monitoring system 'GeoNet', enables emergency management organisations to quickly establish the location and size of a major earthquake and the appropriate response.

New Zealanders will need to be self-reliant for days, if not weeks, after a large earthquake because infrastructure may be damaged over a wide area, with lengthy repair times. The lack of recent damaging earthquakes may have created some complacency, and some people may not be adequately prepared.

Response and recovery

Pre-event recovery planning – identifying in advance the land-use planning decisions that will need to be made during the recovery phase of a large hazard event – is particularly important for earthquakes but has received little attention in the past. One of the challenges in this is weighing the need for communities to regain daily functioning versus the opportunity for more considered planning resulting in increased long-term resilience. This issue warrants more discussion, particularly at territorial authority level in high earthquake-hazard regions.

The Earthquake Commission provides insurance against earthquake damage, up to a certain limit, for residential buildings and contents that are covered for fire damage.

Emergency services and local authorities will be involved in responses to damaging earthquakes. CDEM response to damaging earthquakes follows generic response and recovery procedures set out in CDEM Group plans, the National CDEM Plan and the Guide to the National CDEM Plan.

THE EARTHQUAKE COMMISSION

New Zealand is unique in having the Earthquake Commission (EQC), a government-owned organisation that insures the holders of residential fire insurance against natural hazard damage.

Originally established in 1945 to protect against earthquake and war damage, it now covers earthquake, landslide, volcanic eruption, hydrothermal activity, tsunami, storm/flood (land only), and fire caused by any of these events (war damage was removed in 1994). Residential houses are insured for up to $100,000 worth of damage, and contents for $20,000. EQC's Natural Disaster Fund currently totals $5.4 billion which is reinsured offshore and also backed by a Government Guarantee.

As well as providing insurance, EQC also encourages preparedness through public education, funds natural hazard research and research capabilities including university teaching, engineering standards development, and the national geological hazard monitoring system 'GeoNet'.

FURTHER INFORMATION

GENERAL EARTHQUAKE INFORMATION

GNS SCIENCE
www.gns.cri.nz/what/earthact/earthquakes/index.html
TE ARA ENCYCLOPAEDIA OF NEW ZEALAND
www.teara.govt.nz/EarthSeaAndSky/NaturalHazardsAndDisasters/en

GEONET

GEONET
www.geonet.org.nz

EARTHQUAKE COMMISSION

EARTHQUAKE COMMISSION
www.eqc.govt.nz

EARTHQUAKE ENGINEERING

CANTERBURY UNIVERSITY
www.civil.canterbury.ac.nz/research/research.shtml

BUILDING CODE

DEPARTMENT OF BUILDING AND HOUSING
www.dbh.govt.nz/blc-building-code-and-review

LEAD RUBBER BEARINGS

ROBINSON SEISMIC
www.robinsonseismic.com/products/lrb.html

ACTIVE FAULT GUIDELINES

MINISTRY FOR THE ENVIRONMENT
www.mfe.govt.nz/publications/rma/planning-development-active-faults-dec04/index.html

Bay of Plenty earthquake 1987. Damage to rail infrastructure.
David Plews, Whakatane.