

Environment Canterbury
58 Kilmore Street
P O Box 345
Christchurch
New Zealand

Telephone: (03) 365 3828
Fax: (03) 365 3194
Website: www.ecan.govt.nz

Canterbury Civil Defence
Emergency Management Group
www.cdemcanterbury.govt.nz

August 2008
ECan Publication: E08/116



EARTHQUAKES



THE FILES

- ➔ WHAT CAUSES EARTHQUAKES?
- ➔ HOW DO EARTHQUAKES AFFECT CANTERBURY?
- ➔ ARE YOU REALLY PREPARED FOR AN EARTHQUAKE?

CONTENTS

PAGE 2	What causes earthquakes?
PAGE 2	Measuring earthquakes
PAGE 4	Canterbury's active faults
PAGE 6	The Alpine Fault
PAGE 7	Earthquake hazards
PAGE 10	Canterbury's shaky history
PAGE 12	Managing earthquake risk
PAGE 13	Are you really prepared?

Images on front cover — from left to right

1. Goods train derailed in the 1922 Motunau earthquake.
2. Earthquake resistant Westpac Trust Stadium, Christchurch.
Source: Holmes Consulting Group
3. Rock fall at Arthur's Pass in the 1929 Arthur's Pass earthquake.
Source: Canterbury Museum ref. 14459
4. Looking east along the Hope Fault towards the Hanmer Basin, North Canterbury.

The organisations and individuals involved in the collection and compilation of the information contained in this booklet and those involved in its design, printing and distribution, assume no responsibility for any action taken, or decision made, by an organisation or individual, in reliance on the information presented.

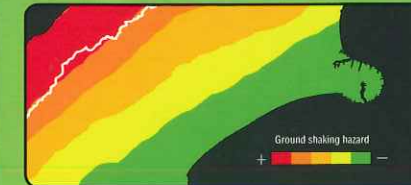


EXPOSING CANTERBURY'S SHAKY FUTURE

Earthquakes are caused by the sudden release of slowly built-up strain along a fault (fracture) in the earth's crust. They can be generated on land or off-shore.

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. The last 60 years have been relatively quiet with only two on-shore earthquakes greater than magnitude 7.

The Q Files dig up the facts about Canterbury's earthquake threat and what you can do to be prepared. A damaging earthquake could occur at anytime...



WHAT CAUSES EARTHQUAKES?

The constantly-moving tectonic plates that make up the earth's crust do not move past each other easily, and stress builds up on and near the boundaries where these plates meet. This stress is occasionally released along planes of weakness, or faults, in the earth's crust. The sudden fault 'rupture' releases a lot of energy, which radiates out from the fault as seismic waves and is felt as an earthquake.

New Zealand lies across the boundary of the Australian and Pacific tectonic plates. To the east of the North Island, the two plates move towards each other, meeting in a collisional boundary called a subduction zone, where the Pacific Plate slides, or subducts, beneath the Australian Plate. To the south of the South Island, the Australian Plate subducts beneath the Pacific Plate. In between, from Marlborough to Fiordland, the two plates try to slide past each other. The movement of the plates is not exactly parallel to the plate boundary, so the edge of the plates have been deformed and pushed up, creating the Southern Alps.



Above: New Zealand's plate boundary location.

MEASURING EARTHQUAKES

Earthquakes are measured in two different ways: magnitude and intensity.

Earthquake magnitude is a measure of the energy released by an earthquake, or its 'size'. The magnitude of an earthquake is determined by measuring the height of seismic waves recorded at several seismograph stations at different locations. Because earthquakes vary a lot in size, earthquake magnitude scales are logarithmic. For an increase of one step in magnitude, the energy

released increases about 32 times. So magnitude 7 is 32 times bigger than magnitude 6, and a magnitude 8 earthquake releases one million times more energy than a magnitude 4 earthquake.

Earthquake intensity, on the other hand, describes how much ground shaking occurred, or how 'strong' the earthquake was, at a particular location. Seismic waves attenuate (weaken) as they travel away from the earthquake source, so an earthquake generally feels less intense the further away from the source

you are. The intensity of earthquake shaking at a particular location depends on the magnitude of the earthquake (how much energy was released at the source), and how deep and how far away it was. Local topography, geology and soils also influence shaking intensity. For example seismic waves are often amplified in soft sediments, or can be focused along ridgelines.

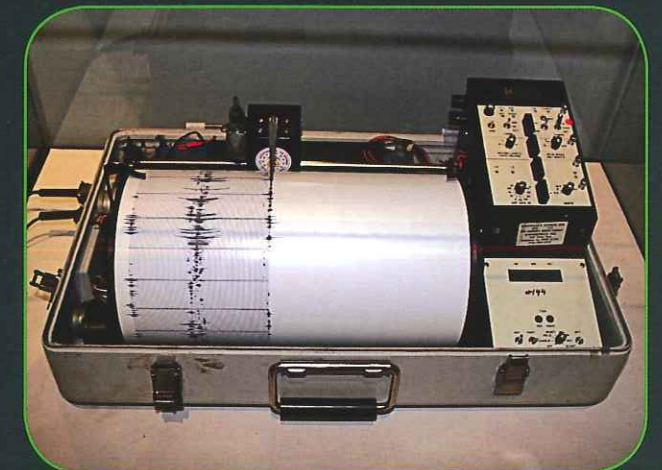
There are a number of intensity scales, but in New Zealand intensity is measured using the Modified Mercalli (MM) intensity scale. This is a descriptive scale from 1 to 12 based on how people feel an earthquake, the damage to buildings and their contents, and how the physical environment responds.

THE MODIFIED MERCALLI INTENSITY SCALE

1. Not felt.
2. Felt by persons at rest or on upper floors of buildings.
3. Felt indoors, like a small truck passing; hanging objects swing slightly.
4. Felt indoors by many, like a heavy truck passing; hanging objects swing, windows rattle.
5. Felt outdoors, sleepers awakened, small objects and pictures move.
6. Felt by all, crockery breaks, furniture moves, weak plaster cracks.
7. Difficult to stand, noticed by car drivers, furniture breaks, weak chimneys break at roof line, and plaster, loose bricks and tiles fall.
8. Driving is difficult, ordinary masonry is damaged, chimneys and towers fall, some liquefaction.
9. General panic, poor masonry destroyed, ordinary masonry and foundations damaged, liquefaction and landslides.
10. Most masonry structures destroyed. Some well-built wooden structures and bridges destroyed. Dams and embankments damaged, large landslides.
11. Few buildings left standing.
12. Damage nearly total.



Above: The general pattern of Modified Mercalli shaking intensity during the magnitude 7.0-7.3, 1888 North Canterbury earthquake on the Hope Fault. Shaking intensity generally decreases away from the source of an earthquake, but can be influenced by local topography, geology and soil.



Above: Seismographs measure ground shaking and record it onto a drum. They provide important information which is used to locate, measure and study earthquakes.

Source: Wikipedia

CANTERBURY'S ACTIVE FAULTS

Faults are planes of weakness in the earth's crust, so they are the most likely areas to move (rupture), creating an earthquake, when stress develops in the crust. Active faults are faults that have ruptured in the past and are likely to rupture again in future.

There are many active faults in and near Canterbury, both on land and offshore. Generally, only large fault ruptures, generating earthquakes of more than magnitude 6.5, will break through to the ground surface, leaving a visible line or scarp along the ground known as a fault trace. There are many mapped fault traces in Canterbury, particularly in the Southern Alps and foothills.

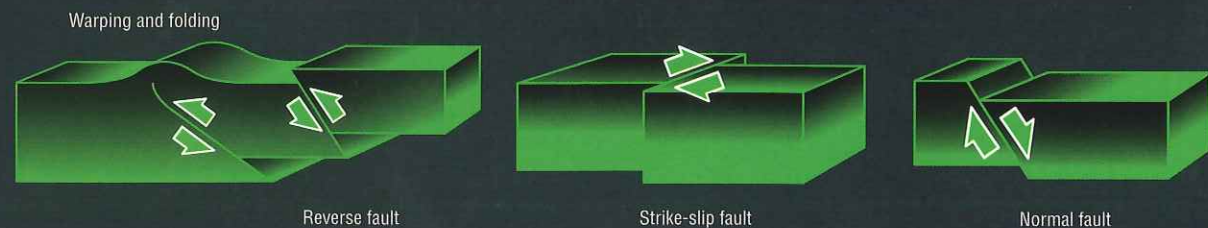
Many faults, however, are entirely underground and are difficult to detect. Sometimes underground faulting produces folding or warping of the ground surface above. There are several of these folds or warps in the gravels of the Canterbury Plains, indicating faults in the bedrock underneath. Often though, these underground faults remain undetected until an earthquake occurs on them.



Above: Digging a trench across the Ashley Fault scarp near Rangiora. Trenching reveals where layers of sediment have been offset by movement on the fault during earthquakes. Organic material within the sediment can be dated to help determine when earthquakes have occurred.

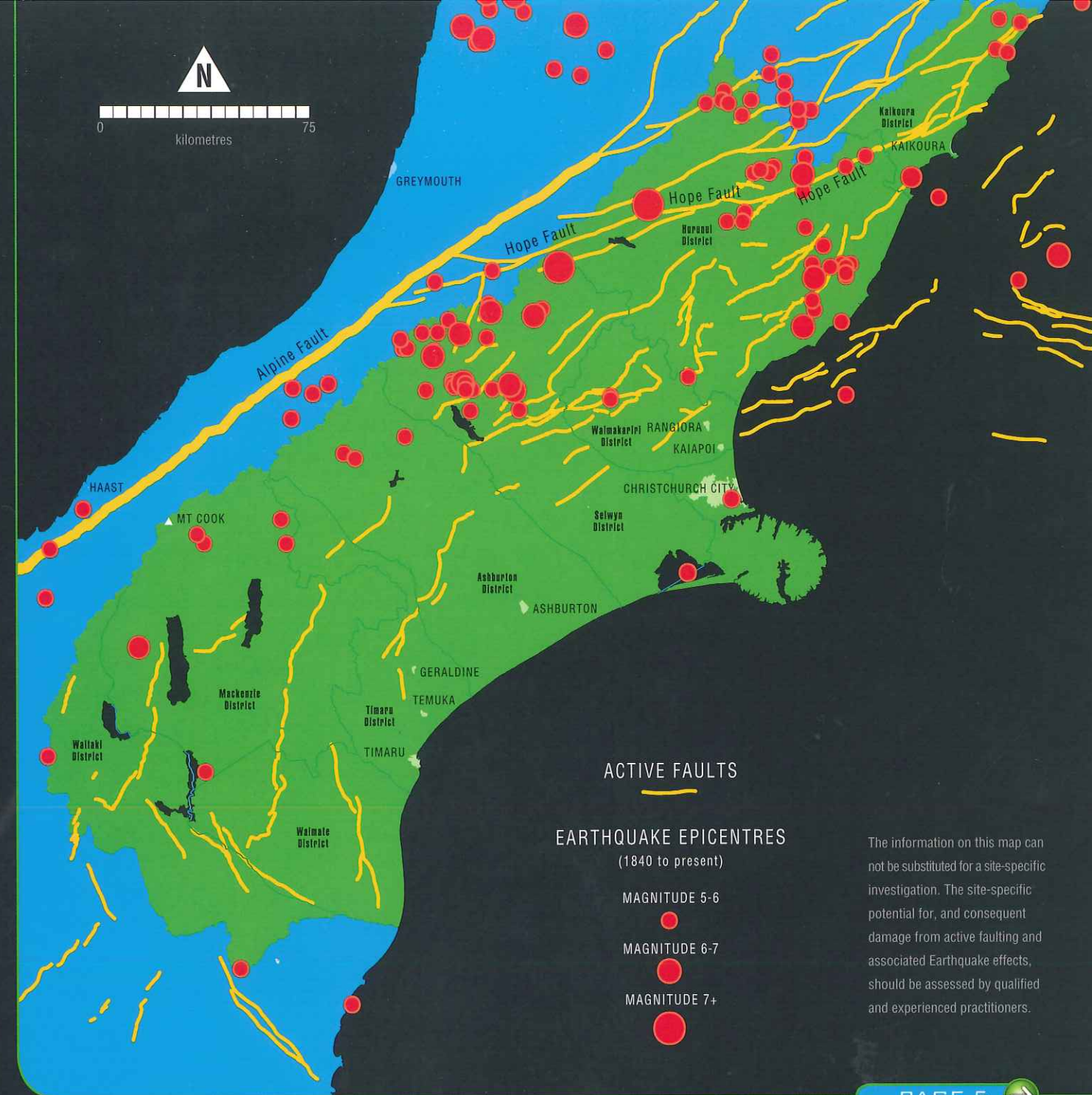
Source: University of Canterbury

FAULT TYPES



Above: Land on either side of a fault may move in different ways depending on whether the crust is being pulled, pushed or twisted. Most faults in Canterbury are reverse or strike-slip faults, or a combination of the two.

Fault traces can provide a geological record of large earthquake activity extending back over many thousands of years. Field studies of major faults can provide information on how often earthquakes have occurred on the fault, and indicate where large earthquakes are likely to occur in future.



ACTIVE FAULTS

EARTHQUAKE EPICENTRES (1840 to present)

MAGNITUDE 5-6



MAGNITUDE 6-7



MAGNITUDE 7+



The information on this map can not be substituted for a site-specific investigation. The site-specific potential for, and consequent damage from active faulting and associated Earthquake effects, should be assessed by qualified and experienced practitioners.

THE ALPINE FAULT



Above: The central South Island, with the west coast at the top of the picture and the east coast and Banks Peninsula in the bottom. The Alpine Fault marks the sharp western edge of the Southern Alps through the image.



The Alpine Fault marks the boundary between the Australian and Pacific Plates and forms the western edge of the Southern Alps. The Alpine Fault has not moved since European settlement but geologists believe it is capable of producing magnitude 7.9-8.2 earthquakes. Evidence suggests that the last earthquake on the fault, involving fault rupture along almost 400km of the fault, occurred in 1717. Previous earthquakes have been dated at around 1430 and 1625.

Estimates of how likely a future Alpine Fault earthquake is vary but most scientists agree that, given the current rate of stress accumulating along the fault, a large earthquake is almost certain within the next 100 years.

The next Alpine Fault earthquake will cause major damage across the South Island. Transport routes will be impassable as bridges are damaged and landslides block roads and railway lines. Water and electricity supplies, communications and food supply networks will be disrupted. If the earthquake occurs in summer, many people will be isolated in tourist locations. It is likely we will need international assistance, and many aftershocks will affect the response and recovery.

The effects of an Alpine Fault earthquake will continue for many years. Landslides in the Southern Alps will supply large volumes of sediment into rivers, which will slowly work its way down valleys and onto plains and coastal areas. This is likely to cause rivers to change course and flood land, particularly on the West Coast with its steep river catchments and high rainfall.

Left: The most probable Modified Mercalli ground shaking intensities for a magnitude 8 earthquake on the Alpine Fault. This size earthquake is the largest earthquake likely to occur on faults in or close to the Canterbury region.

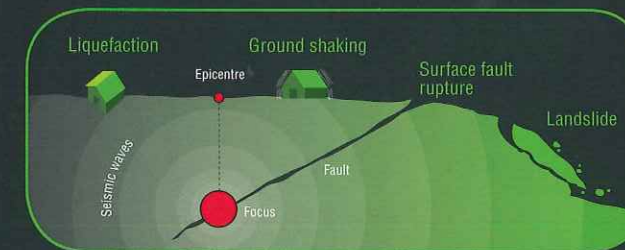
EARTHQUAKE HAZARDS

The energy released during an earthquake creates both local and widespread effects, including ground shaking, surface fault rupture, liquefaction, landslides and tsunamis.

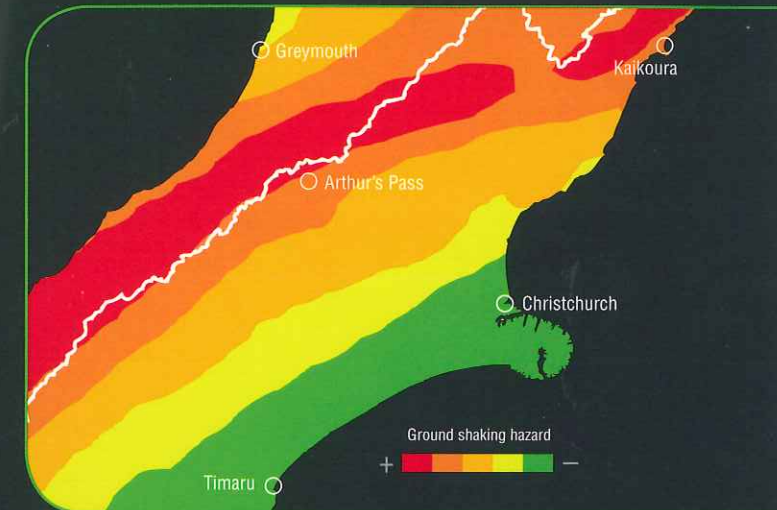
GROUND SHAKING

Most of the damage during an earthquake is caused by ground shaking as seismic waves pass through the earth. The amount of damage depends on how large the earthquake is, how long it lasts and the frequency of the earthquake waves it produces. Large waves put significant stress on man-made structures and, the longer the shaking lasts, the more likely the structures are to sustain serious or permanent damage. Different frequencies of shaking affect buildings differently. In general, low frequency waves affect taller buildings, while high frequency waves affect shorter buildings. Buildings and other structures can be located and constructed in ways to reduce the likelihood of damage and injury from ground shaking.

Aftershocks will occur after a large earthquake as the land adjusts to the displacement that has occurred. These smaller earthquakes can continue for weeks, months or even years after the earthquake.



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



Above: This map shows the relative ground shaking hazard across the central South Island (the white line is the Canterbury region boundary). The redder the area, the more likely it is to experience strong ground shaking. This is based on the location of known active faults as well as historical earthquakes.



Above: An earthquake generates different types of seismic waves. The first waves to arrive at a location are the fastest travelling P or 'primary' waves. P waves generate forward and back movement as the Earth compresses and expands and are often heard rather than felt, hitting a building with a 'bang' or a 'boom'. They are followed by the larger and more destructive S or 'secondary' waves, which shake the ground from side to side, causing structures to vibrate. Shallow earthquakes also generate Love waves, which are the slowest waves but cause the most severe shaking.

EARTHQUAKE HAZARDS (CONTINUED)

FAULT RUPTURE

If an earthquake on a fault is big and shallow enough, generally greater than magnitude 6.5 and less than 40km deep, the displacement on the fault can travel all the way to the ground surface and offset land across the fault, both horizontally and vertically. The two most active faults in New Zealand – the Alpine Fault to the west of Canterbury and the Hope Fault in North Canterbury – move on average every few hundred years, creating large earthquakes and many metres of permanent offset of the ground across the fault. Other faults in Canterbury, further from the plate boundary, may only move every few thousand or tens of thousands of years, with less than a metre of displacement.

Fault rupture at the ground surface will cut underground services, such as water pipes, that cross the fault and can severely damage or destroy structures built across the fault. The fault rupture hazard is confined to a relatively narrow strip along the fault and, because fault rupture tends generally to occur repeatedly in the same place, the areas where it is likely to happen in future can be mapped, and development within those areas can be avoided or minimised.



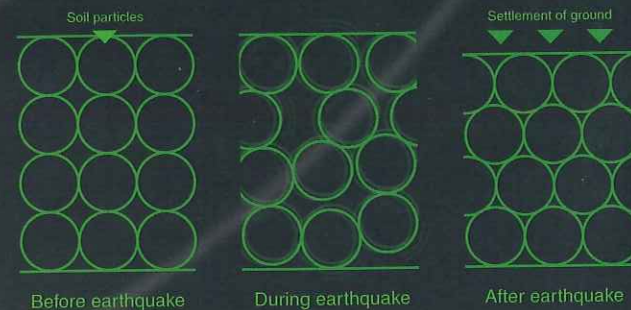
Left: The Edgecumbe Fault ruptured to the ground surface during the 1987 Edgecumbe earthquake, causing up to 2 metres of permanent displacement of the ground.

Source: GNS Science

LIQUEFACTION

Liquefaction occurs when saturated soil is strongly shaken and behaves more like a liquid than a solid. Liquefaction can cause ejection of sand and water onto the ground surface (often called 'sand boils'), ground settlement and lateral spreading where unsupported land, such as riverbanks, move sideways. Damage from liquefaction includes floatation of buried structures like pipes and storage tanks, and tilting or sinking of buildings as the soil loses its strength and ability to support structures.

Liquefaction is most likely in areas where there is saturated, loose sandy and silty soils, or poorly constructed man-made fill, less than 10 to 15 metres below the ground surface. These kinds of sediments occur in parts of coastal areas between Amberley and Lake Ellesmere, and around Timaru. Areas that are most susceptible to liquefaction can be identified and important buildings and infrastructure can be located elsewhere, or the soil can be treated to reduce the potential for liquefaction.



Above: When the ground shakes during an earthquake, soil particles are rearranged and the soil compacts and decreases in volume, causing water to be ejected.

The Q Files – Liquefaction and *The Q Files – The Solid Facts on Christchurch Liquefaction* give more detailed information on liquefaction, its impacts and ways the likelihood of liquefaction can be reduced.



Left: To reduce the potential of damage from liquefaction, a network of stone columns was placed beneath the Paul Kelly Motor Company Stand at AMI Stadium. The stone columns are 600mm in diameter, 8–10m in length and about 1.5m apart. Covering an area of 12,500m², the stone columns improve the strength and stiffness of the soil and provide a path for water to escape should liquefaction occur.

Source: AMI Stadium Ltd.

LANDSLIDES

In New Zealand, landslides are second only to building collapse as a cause of death during earthquakes, having claimed 16 lives in the 1929 Buller earthquake and three in the 1968 Inangahua earthquake. Large earthquakes can cause widespread landsliding, particularly in the steep and highly-fractured Southern Alps.

Landslides in steep valleys and gorges can form dams, which block rivers and create lakes. These dams can be dangerous because they can break suddenly, releasing floodwater down the river. Most landslide dams fail within a few days or weeks, usually during a fresh or flood in the river, but some dams remain for years.

TSUNAMIS

Tsunamis can be generated by earthquakes, either by fault rupture on the sea floor, or by landslides into or under the sea. The most likely source for a significant tsunami for most of the Canterbury coast is a large earthquake off the coast of South America. In the Kaikoura area, the biggest tsunami threat is from a tsunami generated close to shore that could reach the coast in minutes. *The Q Files – Tsunamis* gives more information on tsunamis and how you can be prepared.

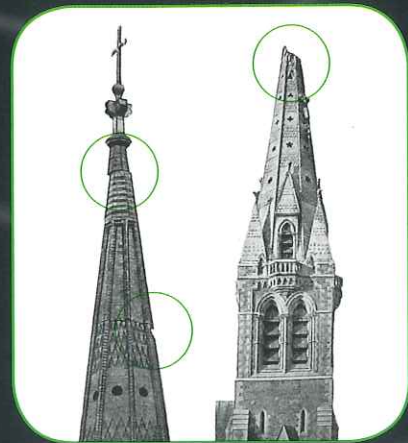


Above: Fifty-five million cubic metres of rock fell from Falling Mountain on the Main Divide during the 1929 Arthur's Pass earthquake and travelled 4.5km down the Oteha River.

Source: GNS Science

CANTERBURY'S SHAKY HISTORY

It is 80 years since Canterbury experienced a large, damaging earthquake. However, in the 70 years between 1860 and 1930, eight earthquakes caused significant building or contents damage in Canterbury.



Above: The Christ Church Cathedral has been damaged by earthquakes on three separate occasions. The most notable was the 1888 North Canterbury earthquake, which caused the partial collapse of the spire. A four-year strengthening programme, completed in 2002, included significant cross-bracing and strengthening to the roof of the side aisles. Four concrete shear walls (walls that give lateral support) were constructed in the transept area and against the west wall.

➔ 04 JUNE 1869
NEW BRIGHTON

DESCRIPTION Magnitude 5, epicentre around New Brighton, MM intensity 7-8 at New Brighton, intensity decreased rapidly away from Christchurch.

DAMAGE Widespread chimney destruction, damage to stone buildings.

REPORTS "The house was violently shaken to the sore destruction of chimneys, crockery and chimney ornaments."

➔ 31 AUGUST 1870
LAKE ELLESMERE

DESCRIPTION Magnitude 5.5, epicentre in the vicinity of Lake Ellesmere, MM intensity 6 in Christchurch, Lake Ellesmere and as far south as Rakaia, felt in Oamaru, Greymouth and Dunedin.

DAMAGE Most damage in Christchurch and Lyttelton - household contents broken, chimneys destroyed, minor structural damage, rock falls.

➔ 5 DECEMBER 1881
CASTLE HILL

DESCRIPTION Magnitude 6.2-6.3, MM intensity 7-8 at epicentre, MM intensity 6 in Oxford and MM intensity 6-7 in Christchurch.

DAMAGE Christ Church Cathedral spire damaged, broken windows, household contents, chimney damage, Avon River stopped flowing.

REPORTS Gladstone Pier at Lyttelton "twisted like a snake".

➔ 1 SEPTEMBER 1888
NORTH CANTERBURY

DESCRIPTION Magnitude 7-7.3, MM intensity 9 at epicentre, MM intensity 5-7 in Christchurch, felt from Taranaki to Southland, surface rupture of the Hope Fault.

DAMAGE Landslides and severe damage to buildings in the Amuri area, damage to Christ Church Cathedral spire, contents damaged.

➔ 16 NOVEMBER 1901
CHEVIOT

DESCRIPTION Magnitude 6.5-7, epicentre near Parnassus, MM intensity 9 in Cheviot, MM intensity 6 in Christchurch, felt from New Plymouth to Dunedin.

DAMAGE Widespread damage to contents, cracks to stone work, broken windows, damaged chimneys and damage to Christ Church Cathedral spire, liquefaction and lateral spreading reported along the Pegasus Bay coast, particularly in Kaiapoi.

REPORTS "A terrible earthquake this morning at a quarter to eight. There is a mass of ruins at Cheviot...shook a traction engine over and a man out of his coffin."

Source: Diary entry, Harry Richard Willis, 16 November 1901

➔ 17 DECEMBER 1922
MOTUNAU

DESCRIPTION Magnitude 6.5-6.7, MM intensity 9 at Motunau and Waipara, MM intensity 6-7 in Christchurch and MM intensity 5 in Ashburton, felt from Taranaki to Dunedin.

DAMAGE Extensive damage in North Canterbury, collapsed chimneys, crockery and household items broken in Christchurch, liquefaction on beaches and river flats.

➔ 9 MARCH 1929
ARTHUR'S PASS

DESCRIPTION Magnitude 7.1, MM intensity 8+ near Arthur's Pass, MM intensity 6 in Christchurch, MM intensity 5+ over most of Canterbury, felt across New Zealand except Northland, source Poulter Fault.

DAMAGE Numerous large landslides in the Southern Alps.

➔ 16 JUNE 1929
BULLER

DESCRIPTION Magnitude 7.8, MM intensity 5-6 across Canterbury.

DAMAGE Damage to roads, bridges, buildings and other structures and 17 deaths in Buller.



➔ 18 JUNE 1994
ARTHUR'S PASS

DESCRIPTION Magnitude 6.7, MM intensity 3-6 in Christchurch, felt from Invercargill to Taranaki, 5,000 aftershocks recorded in the first six days, including two magnitude 6 earthquakes.

DAMAGE Major slips, slumping and cracking of road between Arthur's Pass and Otira and damage to buildings and contents in Arthur's Pass.

➔ 24 NOVEMBER 1995
CASS

DESCRIPTION Magnitude 6.3, felt throughout much of the South Island, magnitude 5.2 aftershock.

DAMAGE Some damage reported at Arthur's Pass, Cass and Mount White Station, minor damage reported from Westport to Christchurch.



Right: McTaggart's butcher shop in Cheviot was severely damaged during the magnitude 6.5-7 Cheviot earthquake in 1901. This photograph shows the damage to the back of the shop.

Source: Canterbury Museum, ref. 1754

MANAGING EARTHQUAKE RISK

Earthquakes happen with little or no warning. Managing our earthquake risk focuses on reducing risk through sensible construction and land-use planning, and planning for how we will respond to and recover from an earthquake. Everyone has a part to play.

REDUCING EARTHQUAKE RISK

Most deaths from earthquakes occur when buildings collapse. New Zealand is a world leader in earthquake engineering – we have resilient houses and high standards for buildings and other structures such as dams. The Building Code, updated in 2004, aims to minimise structural damage, prevent collapse and protect life. However, there are still a significant number of older concrete and unreinforced masonry buildings in Canterbury which have not yet been strengthened.

Ground shaking during a large earthquake is unavoidable but we can identify and manage the type of development in areas where soft sediments may liquefy or faults may offset land at the ground surface. 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 development.

EARTHQUAKE READINESS

Although we can monitor earthquakes, we cannot predict exactly when and where they will occur – we have to be ready all the time. People and communities will need to be self-reliant for days, if not weeks, after a large earthquake. Infrastructure such as roads, communications and water supplies are likely to be damaged over a large area and will take a long time to fix. Emergency services will be very busy with damage and injured people and will not

be able to attend to everyone at once. Because we have not had a large, damaging earthquake in Canterbury for many decades, some people and organisations are not adequately prepared.

RESPONDING TO AND RECOVERING FROM EARTHQUAKES

While emergency services will do their best to respond, a large coordinated response will be required from the Canterbury Civil Defence Emergency Management (CDEM) Group in a big earthquake. The Group comprises all local authorities in the region, along with Police, Fire and St John Ambulance, and the Canterbury and South Canterbury District Health Boards. We may need help from other regions, or even international organisations.

In New Zealand, the Earthquake Commission provides insurance against earthquake damage, up to a certain limit, for residential buildings and contents that are covered by fire insurance.

Pre-event recovery planning – identifying in advance the land-use planning decisions that will need to be made after a disaster – is particularly important for earthquakes, but has received little attention in the past. One of the challenges is weighing up the need for communities to get back to normal as soon as possible, with the opportunity for more considered planning, making more resilient communities in future.

ARE YOU REALLY PREPARED?

The danger you face in an earthquake comes mainly from falling items and collapsing structures such as buildings. You need to be aware of these hazards to help you get through.

BEFORE AN EARTHQUAKE

- Develop a Household Emergency Plan and prepare emergency survival supplies so that you can cope with being on your own for at least three days.
- Check your household insurance policy.
- Seek qualified advice to make sure your house is secured to its foundations. Also check that any renovations comply with the Building Code.
- Secure heavy items of furniture to the floor or wall.

For more information on how to 'quake-safe' your home, go to www.eq-iq.org.nz



DURING AN EARTHQUAKE

- If you are inside a building, stay in the building but move to a safe place (under a table, next to an interior wall, but move no more than a few steps).
- If you are outside, move no more than a few steps, then drop, cover and hold.
- If you are driving, pull over and stop.
- If you are at the beach or near the coast, drop, cover and hold, then move to higher ground immediately in case a tsunami follows the earthquake.

AFTER AN EARTHQUAKE

- Stay calm and check for any injuries.
- Check on people around you and, if you can, help those who need it.
- Check for fire and turn off gas, electricity and water if safe to do so.
- If you are in a damaged building, try to get outside and find a safe, open place – and if possible take with you strong shoes and adequate clothing.
- Listen to the radio for information.
- Be ready for aftershocks.
- Note and photograph property damage for insurance purposes.

MORE INFORMATION ABOUT EARTHQUAKES

The following websites have lots of information on earthquakes, or ask at your local library for earthquake resources:

- Environment Canterbury: www.ecan.govt.nz/naturalhazards
- Institute of Geological and Nuclear Sciences (GNS Science): www.gns.cri.nz
- GeoNet: www.geonet.org.nz
- Earthquake Commission: www.eqc.govt.nz
www.eq-iq.govt.nz
- Quaketrackers: www.quaketrackers.org.nz
- Ministry of Civil Defence & Emergency Management: www.civildefence.govt.nz
www.getthru.govt.nz
- Te Ara: The Encyclopaedia of New Zealand: www.teara.govt.nz

For more information on earthquake hazard management in your local area, contact your city or district council.

