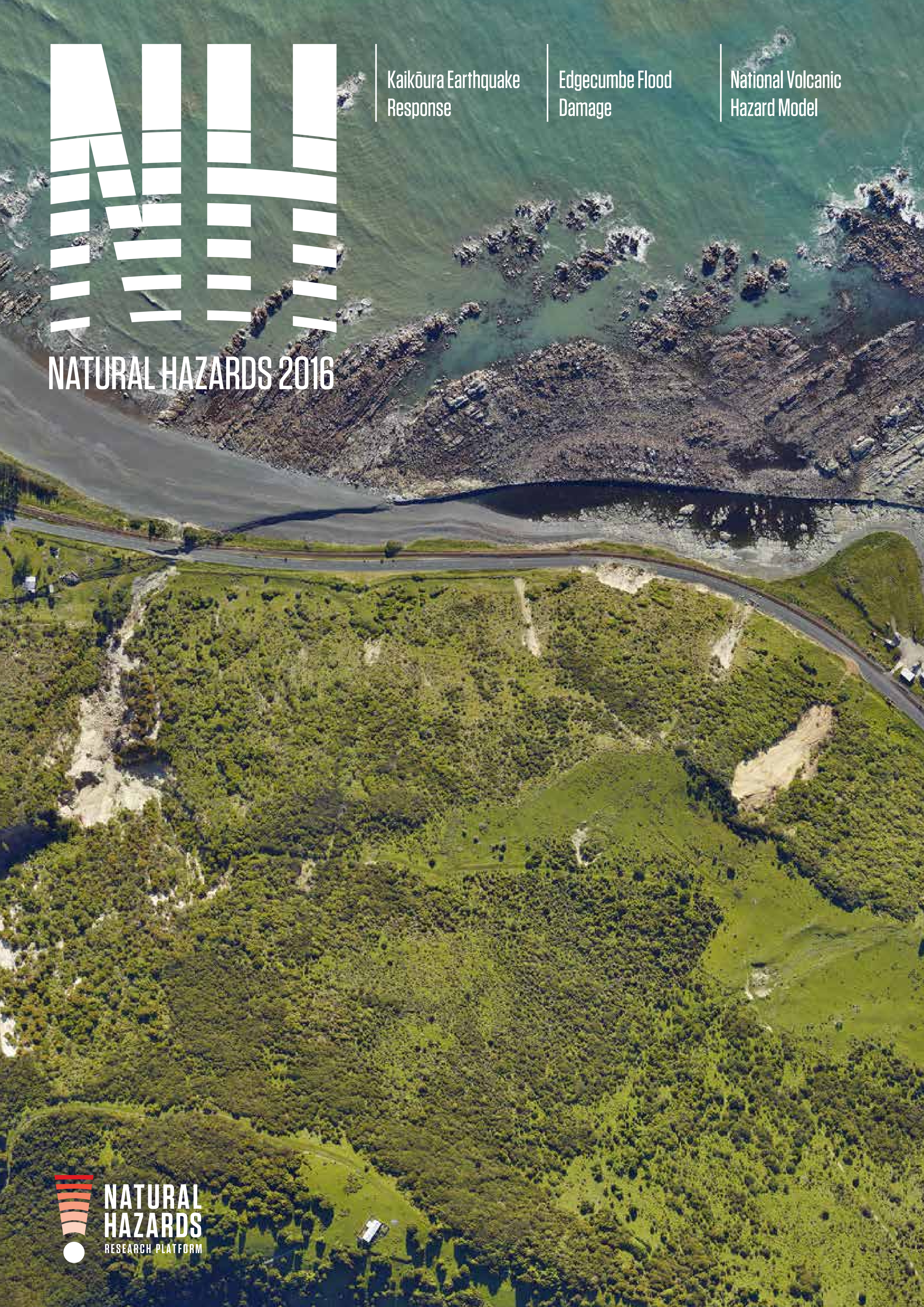


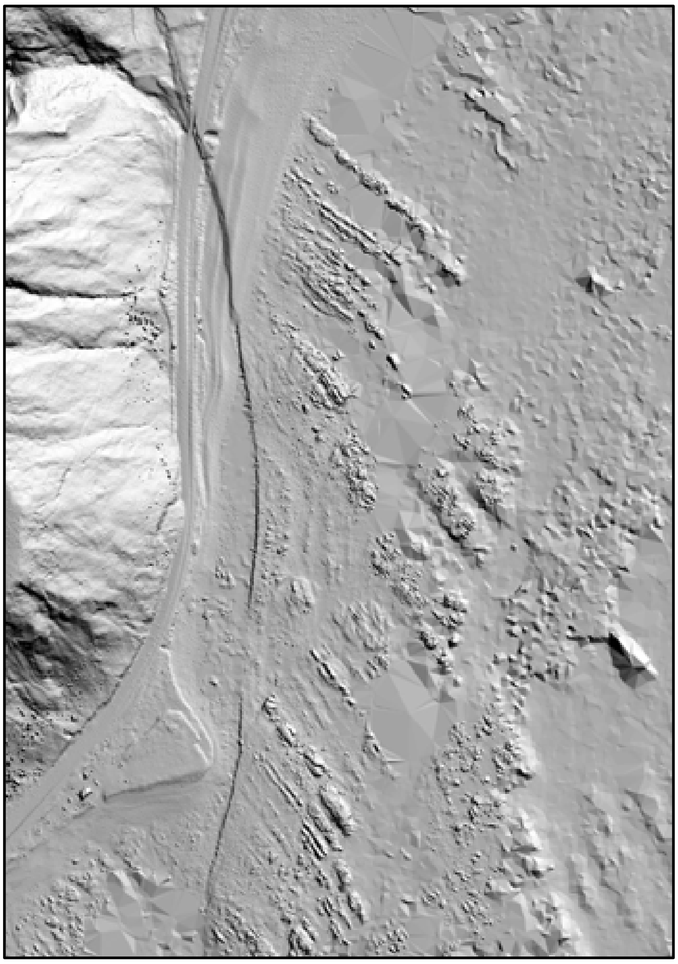
NATURAL HAZARDS 2016

Kaikōura Earthquake Response

Edgecumbe Flood Damage

National Volcanic Hazard Model

NATURAL HAZARDS RESEARCH PLATFORM



These images are LiDAR digital terrain models taken at Waipapa Bay before (left) and after (right) the Kaikōura earthquake. As shown here and on the cover, rupture of the Papatea Fault produced a sharp fault scarp across the land and seabed, and uplifted the coastline by 2 – 6 m at this location. LiDAR provided by ECAN and LINZ.

Cover credits

Uplift and fault scarp at Waipapa Bay. Aerial imagery provided by New Zealand Transport Agency (NZTA) for Land Information New Zealand (LINZ), Image available under Creative Commons 3.0.

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FOREWORD

A spate of natural hazards over the past year has reminded us all of the need to be prepared for an emergency.

Most significant, of course, was the November 14 Kaikōura Earthquake, which disrupted lives and destroyed property from Hurunui to Wellington. It has also become one of the most analysed earthquake events in history.

Severe weather events led to widespread flooding and wind damage, displaced communities and severely damaged infrastructure. In early 2017, ex-tropical cyclones caused extensive damage in the upper North Island, including flooding much of Edgecumbe.

We also contended with the impact of large landslides, with significant consequences for communities along the coast and rural interior from North Canterbury to Marlborough, the Manawatu Gorge, and throughout the Wellington region.

Our ability to respond quickly and effectively to these events depends on our level of understanding of the risk from natural hazards. Investing in our long-term natural hazards research capability means we can respond appropriately when these events occur.

The agencies partnering in the Natural Hazards Research Platform play a vital role in coordinating information and providing expert advice to civil defence, engineers, councils and the general public.

Immediately after the 14 November earthquake, the Government made additional funds available to the Platform which enabled immediate data collection and research that characterised changes to risk resulting from that event.

In Budget 2017, we committed to investing $19.5 million over four years to enhance New Zealand's earthquake, tsunami, landslip, and volcano monitoring capability. It is a significant investment that will equip us with both long-term and real-time information about natural hazards, and enable the development of an enhanced 24/7 natural hazards monitoring capability.

This is an important shift away from "managing disasters" – disasters do not even need to occur if you understand and take actions to avoid placing lives and property in harm's way, or build infrastructure, communities and businesses that are resilient to disruption.

Now in its eighth year, the Platform will soon become part of the Resilience to Natures Challenges National Science Challenge. During its existence, the Platform has consistently delivered high quality, international respected research – even appearing on the cover of Science this year. The Platform's work has tangibly increased the ability of businesses and industries, local and regional authorities, communities and iwi organisations to plan for or avoid loss from natural hazards. This truly is science that benefits all New Zealanders.

Hon Paul Goldsmith
Minister of Science and Innovation

PLATFORM MANAGER'S PERSPECTIVE

The past year has been a particularly busy time for natural hazards researchers.

In late August 2016, Exercise Tangaroa, a national exercise to test our preparedness for a large-scale tsunami event, was followed days later by the 2 September M7.1 East Cape earthquake which triggered a small tsunami. The proximity of the exercise to a real event provided some key lessons, including how we could improve our communication with officials, each other and the public during a crisis.

But it was the hazard events of late 2016 and into 2017 that really tested our resolve. The 14 November 2016 M7.8 Kaikōura earthquake started shortly after midnight, rupturing at least 21 faults from Waiau towards offshore Wellington, and triggered a damaging tsunami at Little Pigeon's Bay, Banks Peninsula. In the light of day, massive landslips, rockfall, coastal uplift, extensive fault surface rupture and property damage were evident. The ground shaking felt in Wellington impacted mid-rise buildings in the CBD and later led to widespread building inspections, business disruption, and in some instances, demolition. Our science funder the Ministry of Business, Innovation and Employment provided $3.2M in research funding to address some of the immediate and extended research needs, highlighted on pages 16-17 of this issue.

While events continued to unfold as a result of the earthquake and a National Recovery office had been mobilised, thoughts of a calmer 2017 came to a halt with the Port Hills fires, followed a short while later by the Edgecumbe floods brought on by the aftermath of Cyclone Debbie. And as I write this, a wet winter has brought additional landslips that have blocked state highways and other transport links.

We don't have control over the weather or the physical processes beneath us, but in our small country we have each other. Family/whānau, friends, neighbours, work mates, colleagues - our relationships with each other pulled us through.

In closing, I would like to acknowledge the widespread research response and commitment to the greater good shown by many across New Zealand's institutions, including colleagues from overseas who offered equipment and a helping hand.

It was a humbling year, with amazing science to support recovery efforts, goodwill and generosity. Here's wishing us all a gentler entry into 2018.

Catherine Pinal
Manager,
Natural Hazards Research Platform


Hawke's Bay snowstorm.
Photo: Bevan Percival, NZTA

A COLD AUGUST NIGHT

by
RICHARD TURNER, NIWA

In early August 2016 a well-forecast and strong winter storm was located over the upper North Island. The storm's strong cold south-easterly winds brought heavy rain to the Hawke's Bay and heavy snowfall at elevations above 400m in the ranges and over the Taupo plains area.

Around 3 am on 6 August, a fault occurred on the Wairakei to Whirinaki line - one of two Transpower 220 kV circuits supplying the Hawke's Bay - causing power outages to 50,000 homes and businesses. The likely cause was a combination of strong winds knocking snow off conductors which had swung close together and caused flashovers. Additionally, a heavy snow load on the Taupo Plains power lines caused damage and widespread power cuts in that area.

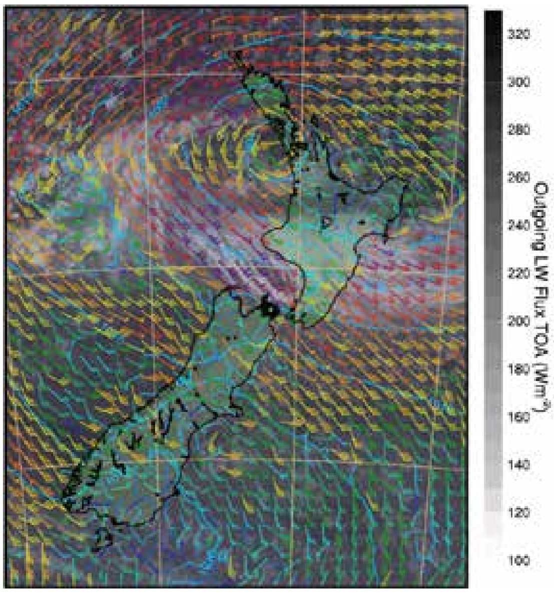

Fig 1a: 18-hour NZCSM forecast of wind barbs, mean sea-level pressure and outgoing LW Flux at the top-of-atmosphere (white areas are cold cloud tops) valid at 1500 UTC, 5 August 2016 (0300 NZST 6 August). Data: NIWA.

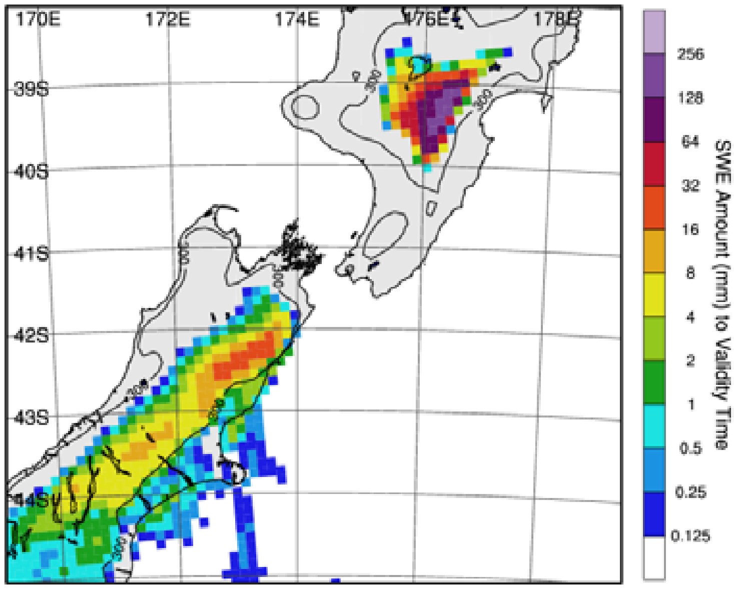

Fig 1b. 24 hour NZLAM forecast snowfall accumulation (liquid water equivalent mm) for period ending 0000 UTC (noon NZST) 6 August 2016 over central New Zealand. Data: NIWA.

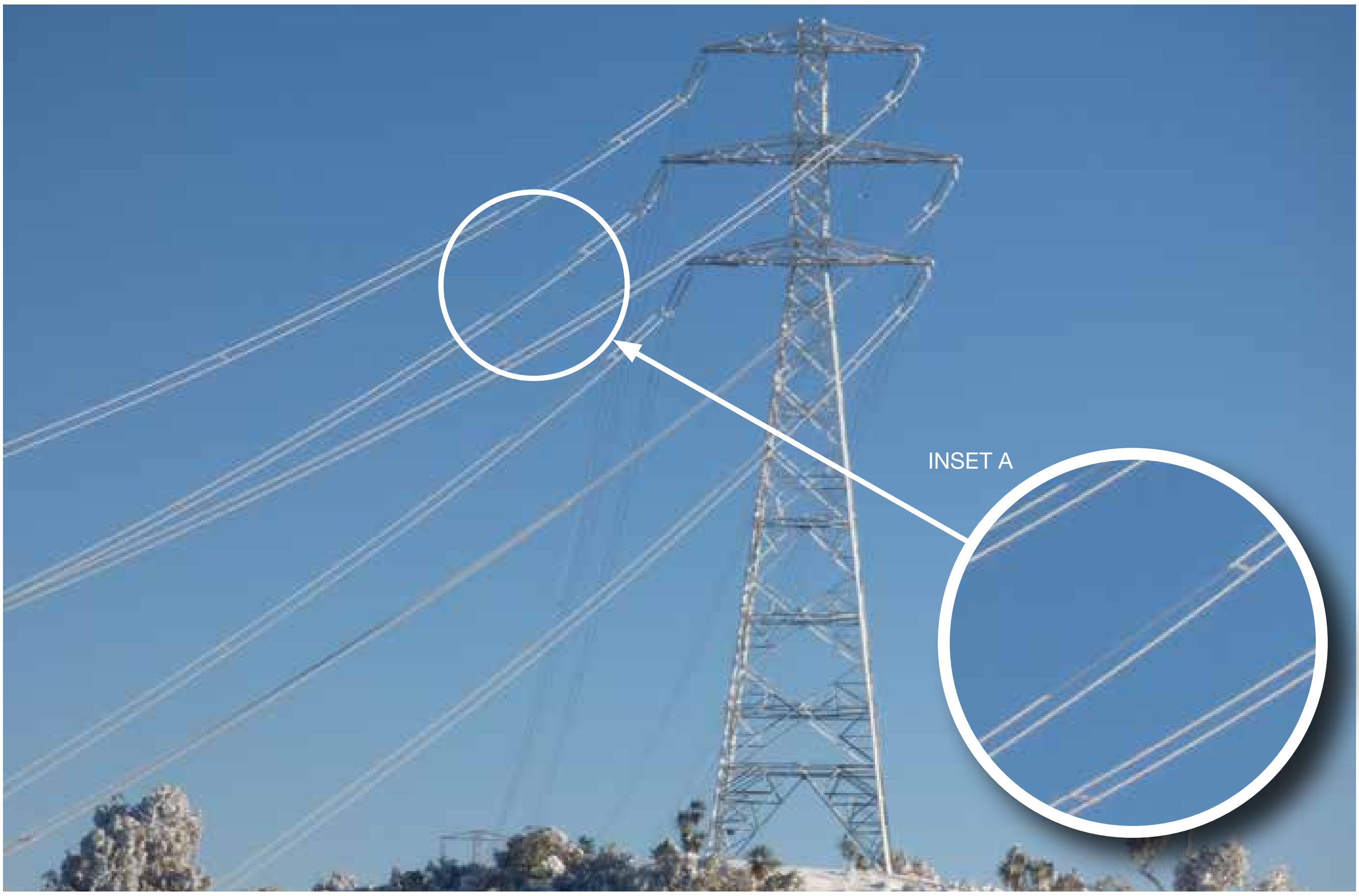

Fig. 2. Snow and Ice accretion (INSET A) on a high elevation span of HVDC line WRK-WHI-A on 7 August at the eastern edge of Rangitaiki plain. Photo: Alan Lyne, Transpower.

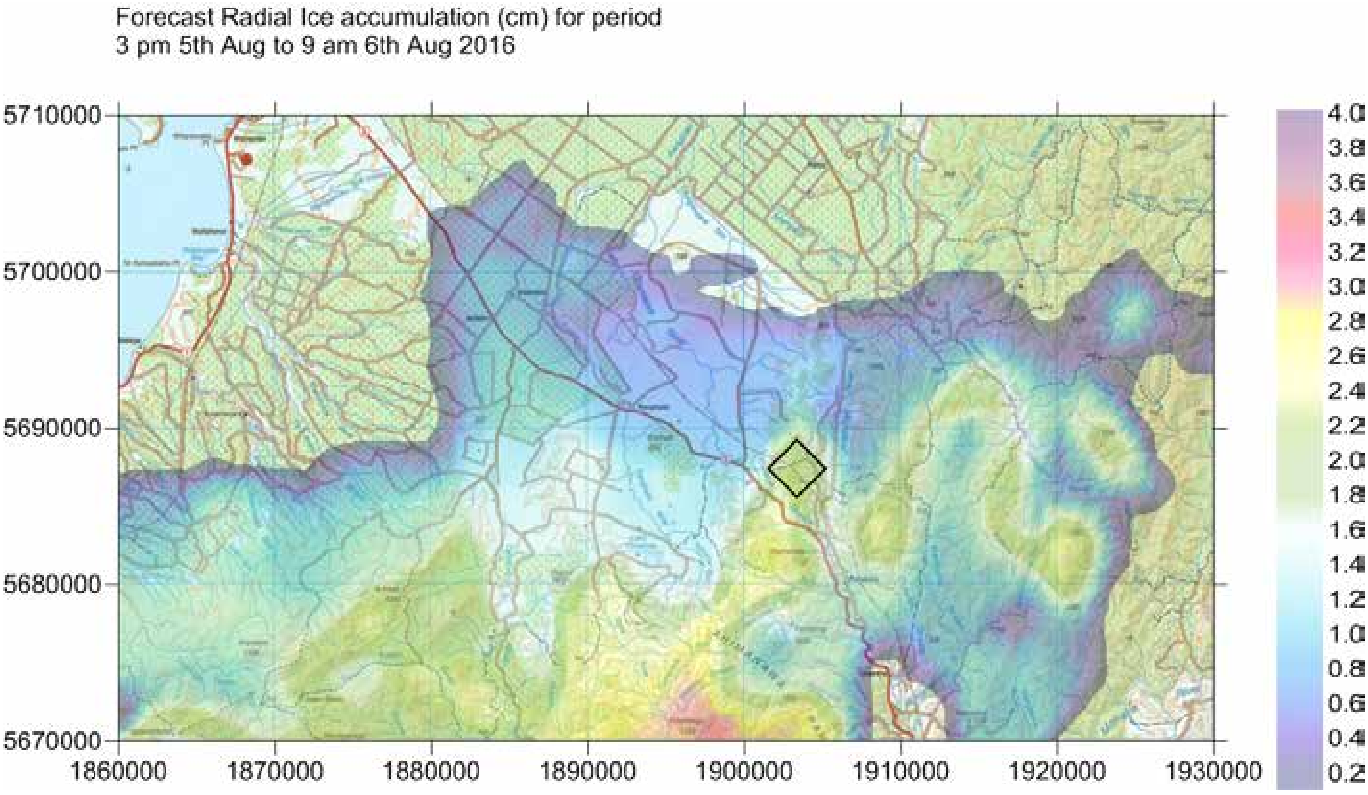

Fig. 3. Forecast (based on NZCSM forecast meteorological parameters) of radial ice accumulation (cm) over the Rangitaiki plain area for 18 hour period ending 2100 UTC 5 August 2016 (0900 NZST 6 August) assuming conductor of 26 mm diameter (the coordinates are NZTM), the black diamond is the location of the span in Fig 2. Data: NIWA

Applied Forecasting Products

NIWA's Climate, Atmosphere, and Forecasting Program is researching the development of applied forecast products that exploit advances in Numerical Weather Prediction capability such as the increased spatial resolution available from NIWA's NZCSM (a 1.5 km grid spaced operational and research weather model). One such product is the forecast of radial ice build-up on transmission lines. One possible cause for flashover is 'galloping', a dynamic response of the line to strong winds knocking snow off conductors which had swung close together. HVDC (High Voltage Direct Current) spans are designed so that large fluctuating movements do not occur, even in extreme winds. However, radial-ice build-up can cause a change in the cross-sectional characteristics of the conductor span which may make it more susceptible to a dynamic response at strong speeds. It is important to identify situations in which significant radial-ice build-up can occur, as one option is to send more current down a line to try and melt the ice.

How ice build-up occurs

Radial ice build-up is a function of the rate of snowfall, temperature, relative humidity, wind speed and direction of wind relative to the line. This occurs with high humidities, temperatures of 0-1°C, high snow rate, and moderate wind speeds across the lines. Increased spatial resolution from NZCSM allows more accurate wind speed and direction forecasts, representation of physical processes that lead to high snow rates, and an improved rendering of spatial variations in temperature and humidity.

Fortunately, after this storm, aerial photos were taken and these show radial ice build-up on spans near tower 110 of WRK-WHI-A as shown in Fig. 2. The conductors are about 26 mm in diameter, and from the photo the radial ice appears to be 20–30 mm thick – in total about double the diameter of ice-free span. This compares with the NZCSM forecast of around 18–24 mm of radial ice (see Fig. 3). The location of pylon 110 is in the area of the black diamond. However, getting good information to verify radial ice forecasts and other snow products such as ground snow loads (i.e., the weight of snow – which depends on the density of the snow) is difficult but can be improved.

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SEISMOLOGY IN ACTION: EARTHQUAKE RESPONSE

by
CAROLINE HOLDEN AND THE GNS SCIENCE SEISMOLOGY TEAM

GeoNet technicians install a new GNSS and Strong Motion seismic station following the Kaikoura Earthquake. Location: near Lake Tennyson, North Canterbury. Photo: Lara Bland

Watching the earthquake unfold

Geodesy and geological observations have provided a very detailed picture of the M7.8 Kaikōura earthquake sequence. The addition of a time element from the GeoNet seismic network allowed us to capture the few minutes that it took for the earthquake to unfold along the east coast of the South Island.

Multiple source modelling techniques suggest that the earthquake ruptured, more or less continuously, more than 20 fault segments from south to north and went on for more than 90 seconds. The dominant energy release actually occurred in the northern part of the rupture area, roughly 60 km south of Wellington, about 60-70 seconds after rupture initiation.

Providing rapid information about ground shaking

Seismic instruments from GeoNet, including building arrays, allowed detailed capture of the ground shaking in terms of intensity, duration and frequency. The earthquake was felt widely across the whole of New Zealand and was strongly felt in towns closest to the rupture, including Waiau, Ward and Seddon, as well as in the larger urban centres of Kaikōura, Hamner, Blenheim and Wellington. The epicentre was located about 100 km north of Christchurch but the rupture extended 200 km further north and appears to have stopped about 50 km south of Wellington.

GeoNet's extensive strong motion and broadband networks captured ground motion all over the country and recorded extreme ground motions of over 1g at both ends of the rupture in Waiau, Ward and Kekerengu, as well as ground motions exceeding design levels for particular periods in the Wellington region.

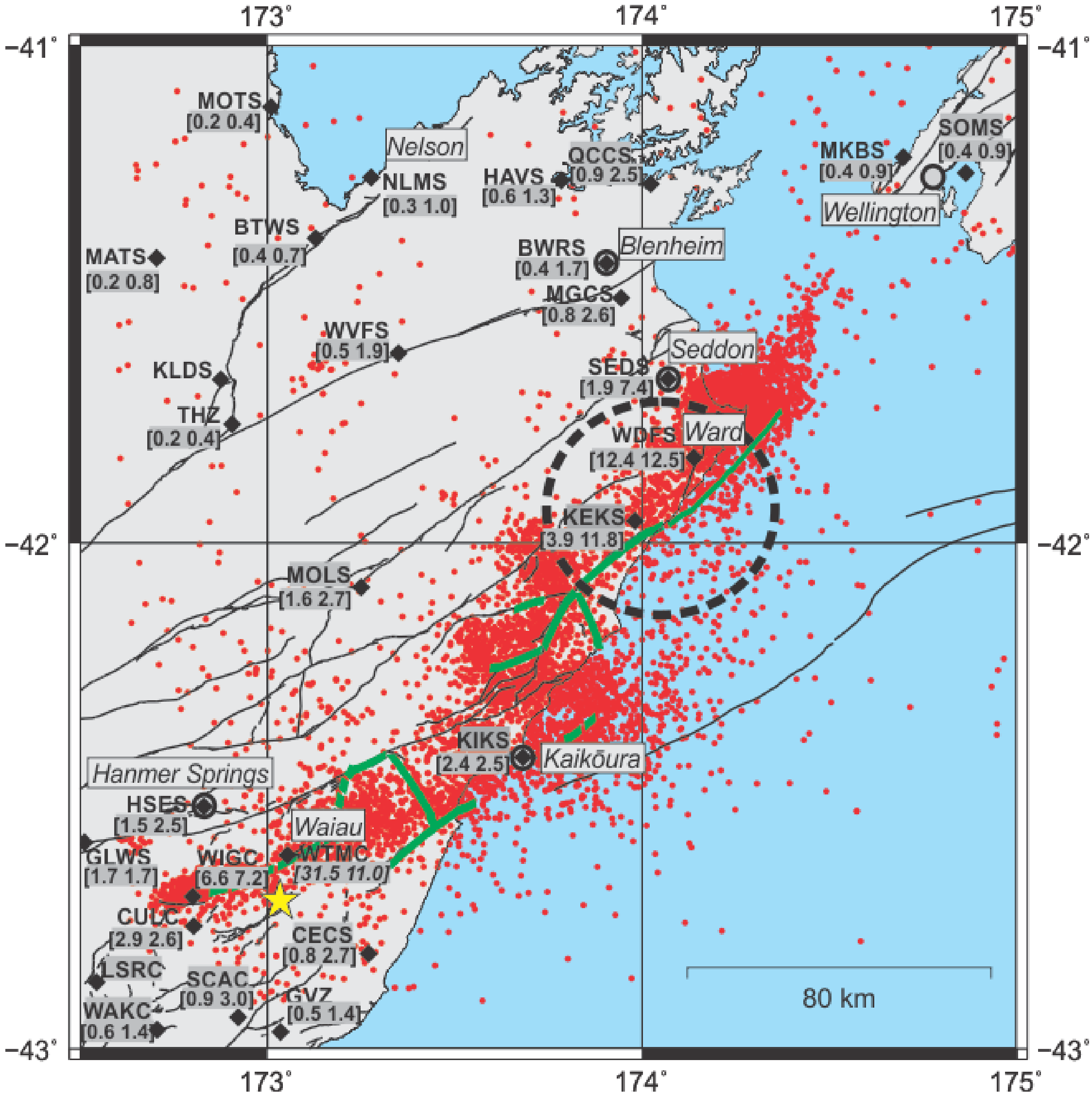

Fig 1. The Mw7.8 Kaikōura earthquake: the yellow star shows the epicentre location; red dots the aftershocks of Mw2.5 and greater (from 13 November 2016 to April 2017). Surface fault ruptures are shown in green; dashed circle shows the area that released the most energy during the earthquake. Black diamonds are GeoNet strong-motion stations (with associated peak accelerations [vertical, horizontal] in m/s/s). For clarity not all GeoNet stations for Nelson, Blenheim and Wellington are represented on this figure.

Understanding the underlying geology to produce better earthquake forecasts

Recent seismological studies provide detailed insight into the crustal structure beneath central New Zealand. In particular, the data show that the region is characterised by a transition zone near Cook Strait where the well-defined Hikurangi subduction interface to the north becomes more complex to the south. A recently deployed dense seismic array is tracking aftershocks in the Seddon area in order to monitor underlying geological structures responding to the Kaikōura earthquake.

A better understanding of the earth's crustal structure is critical in order to provide better seismic hazard forecasts. The Kaikōura earthquake was followed by regional aftershock triggering. It was also followed by widespread triggering of seismicity across the North Island and unprecedented slow slip events in the Hikurangi subduction zone capable of producing very large earthquakes. The impact of the slow slip events on aftershock forecasts and future behaviour of the subduction interface are currently being assessed.

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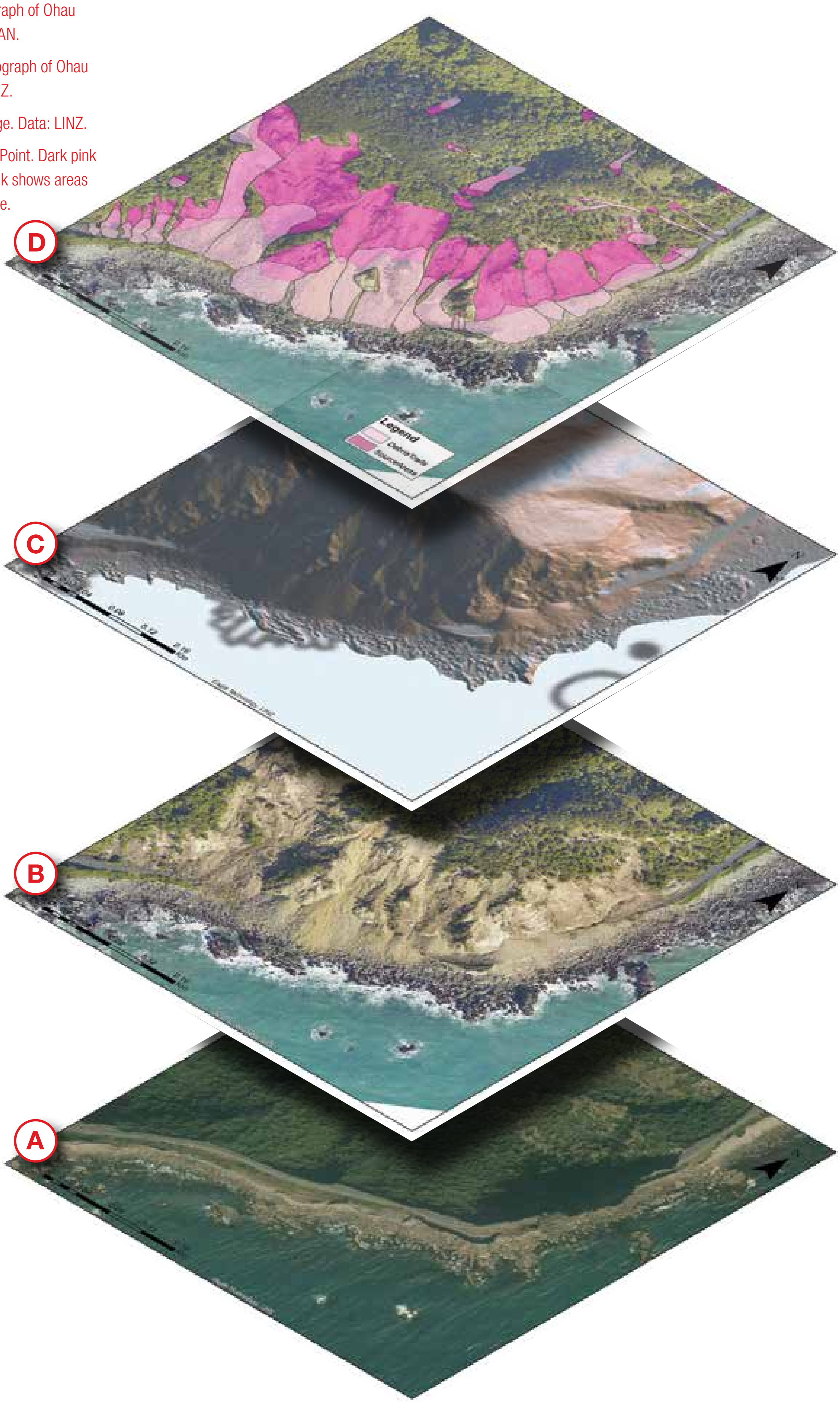
A. Pre-earthquake aerial photgraph of Ohau Point, North Kaikōura. Data: ECAN.

B. Post-earthquake aerial photograph of Ohau Point, North Kaikōura. Data: LINZ.

C. Post-earthquake LIDAR image. Data: LINZ.

D. Landslides mapped at Ohau Point. Dark pink shows areas of erosion; light pink shows areas of deposition. Data: GNS Science.



IMAGERY TO MAP LANDSCAPE CHANGES: KAIKŌURA EARTHQUAKE

by
SALLY DELLOW, GNS SCIENCE

The variety of imagery available is becoming increasingly important to our ability to understand the impacts of natural hazards on the landscape.

In the first few days after a major event, photographs and radar-based imagery such as InSAR help us identify where the ground has been displaced by landslides, active faults or liquefaction.

Not all imagery is at the same scale or resolution (our ability to see detail) or rectification (our ability to align a new image with existing maps). For example, most satellite images are taken obliquely or at an angle, and are more difficult to rectify into pre-existing imagery than are vertical aerial photographs.

The other consideration is the trade-off between speed and accuracy. The ability to get information out to emergency managers and asset owners immediately after an event is important to help them understand impacts and to plan response activities. But as time moves on, accuracy is more important as recovery gets underway and repairs and reinstatement require quantification of the damage.

In the days immediately following the Kaikōura earthquake, we relied on oblique aerial photographs of landslides, which enabled the extent and severity of the landslide damage to be understood. This was supported by satellite images taken when conditions were optimal with minimal cloud cover.

As time went on, new vertical aerial photographs and post-earthquake LiDAR were acquired. The advantage of these images is that it means we now have a catalogue of nation-wide vertical aerial imagery and LiDAR, from before and after the earthquake. This allows us to superimpose the imagery and measure differences that have occurred. This information can be used to calculate landslide volumes with a degree of accuracy not previously available, and determine the equipment required for debris removal to reinstate roads, or estimate the volume of material that could potentially re-mobilise in rainstorms affecting a site for years to come.

On a smaller scale, drones and a terrestrial laser scanner have been used to develop 3-D models of some of the landslide dams that formed, (*see next page*). This has allowed us to see changes in the landslide dams over time, and development of seepage points and overflow channels. We have been able to capture the changes and show that landslide dams are dynamic features.

The strength of multiple image sources lies in the ability to combine different images over time to get an ongoing picture of changes in the landscape. The changes can be hazardous, but as we understand the processes driving them we are better able to monitor and predict future changes to reduce risk to people and assets over time.

World view satellite image. This low resolution image was one of the first views available worldwide of Kaikōura earthquake damage. The satellite view aids responders in understanding the extent of damage. Depending on its timed orbit, satellite imagery can provide a sequence of images taken once every week or more. Location: SH1 north of Kaikōura township.

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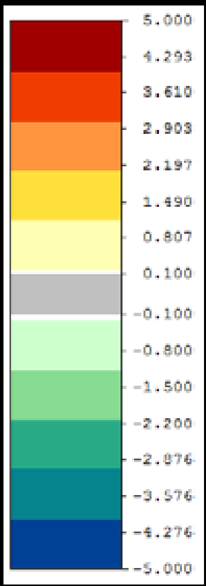
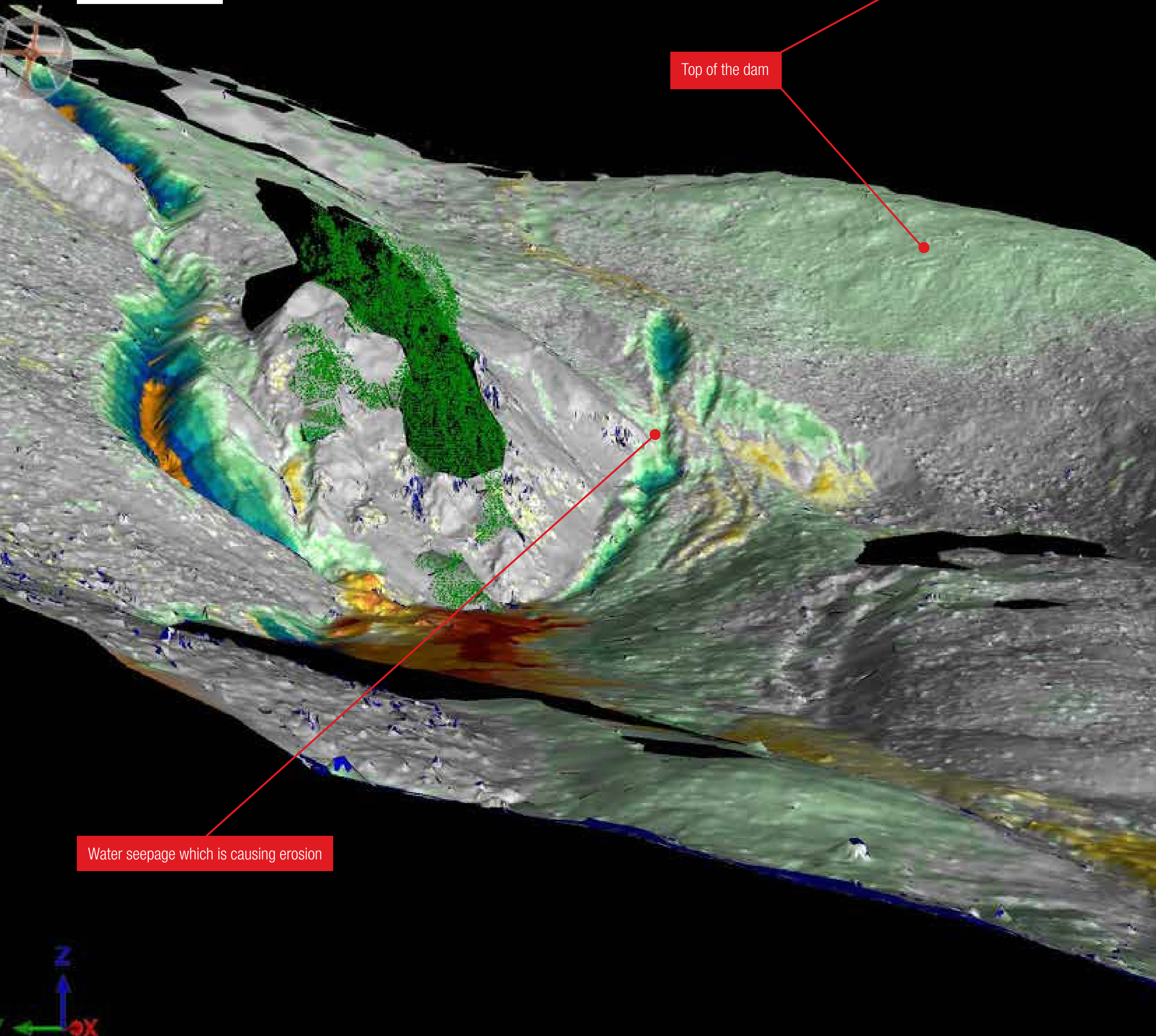
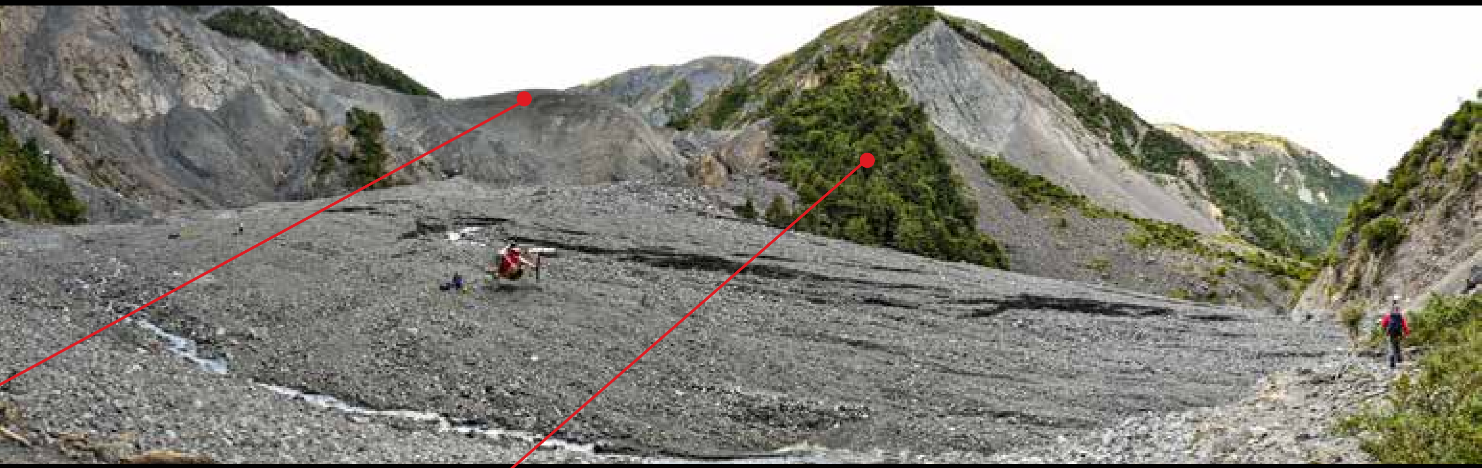


The point cloud image is a comparison/change map based on surveys 15 Dec 2016 vs 28 MAR 2017.

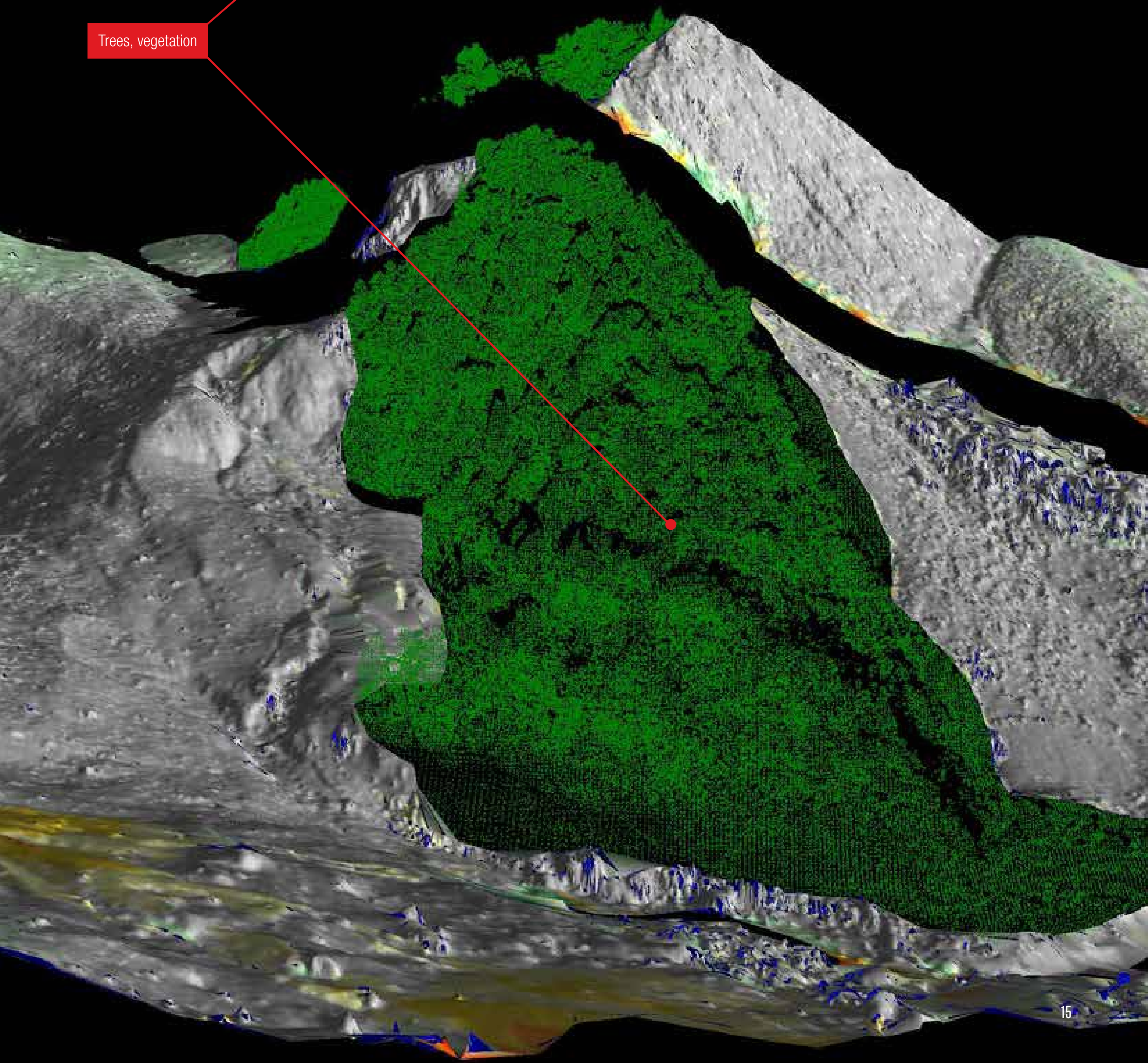
Green/blue shades represent loss of material or consolidation; yellow/red shades represent gain of material or aggradation.

Laser scan technology was utilised in Redcliffs during the Christchurch earthquake sequence, and allowed scientists to quantify the volume of material that fell off the cliffs to level of shaking. Results from those studies informed red zone decisions. Data: GNS Science.





Scientists inspecting Hapuku Dam, Kaikōura Ranges



KAIKŌURA EARTHQUAKE RESPONSE

Geotechnical characterization of CentrePort reclamations

Misko Cubrinovski, University of Canterbury, University of Auckland, Tonkin & Taylor, USA universities

- CentrePort is a key import/export hub; performance of ports vital to an economy.
- The research team is contributing to assessment of liquefaction of reclaimed land and performance of land, wharves and buildings.
- Findings will be relevant to other areas of reclaimed land.

Improving economic model estimates of central government productivity losses

Erica Seville, Resilient Organisations, Market Economics, GNS Science

- Evaluate economic impact of business relocation due to building damage
- The MERIT software tool will be utilised in the data analysis and recalibration of the productivity functions.

Updated NZS 1170.5 subsoil site class and site period maps for the Wellington CBD

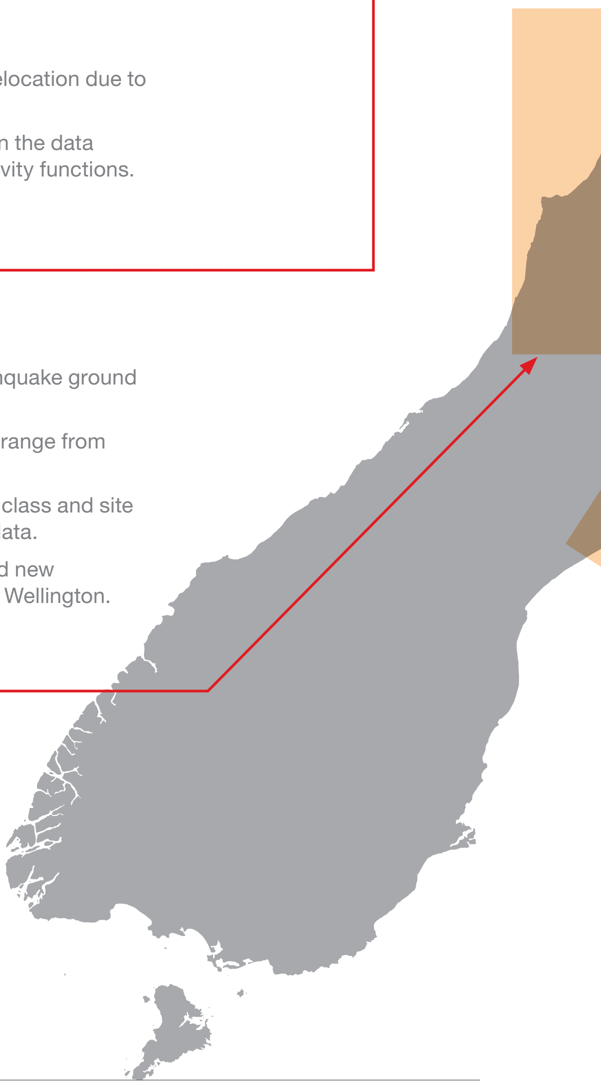
Anna Kaiser, GNS Science & University of Auckland

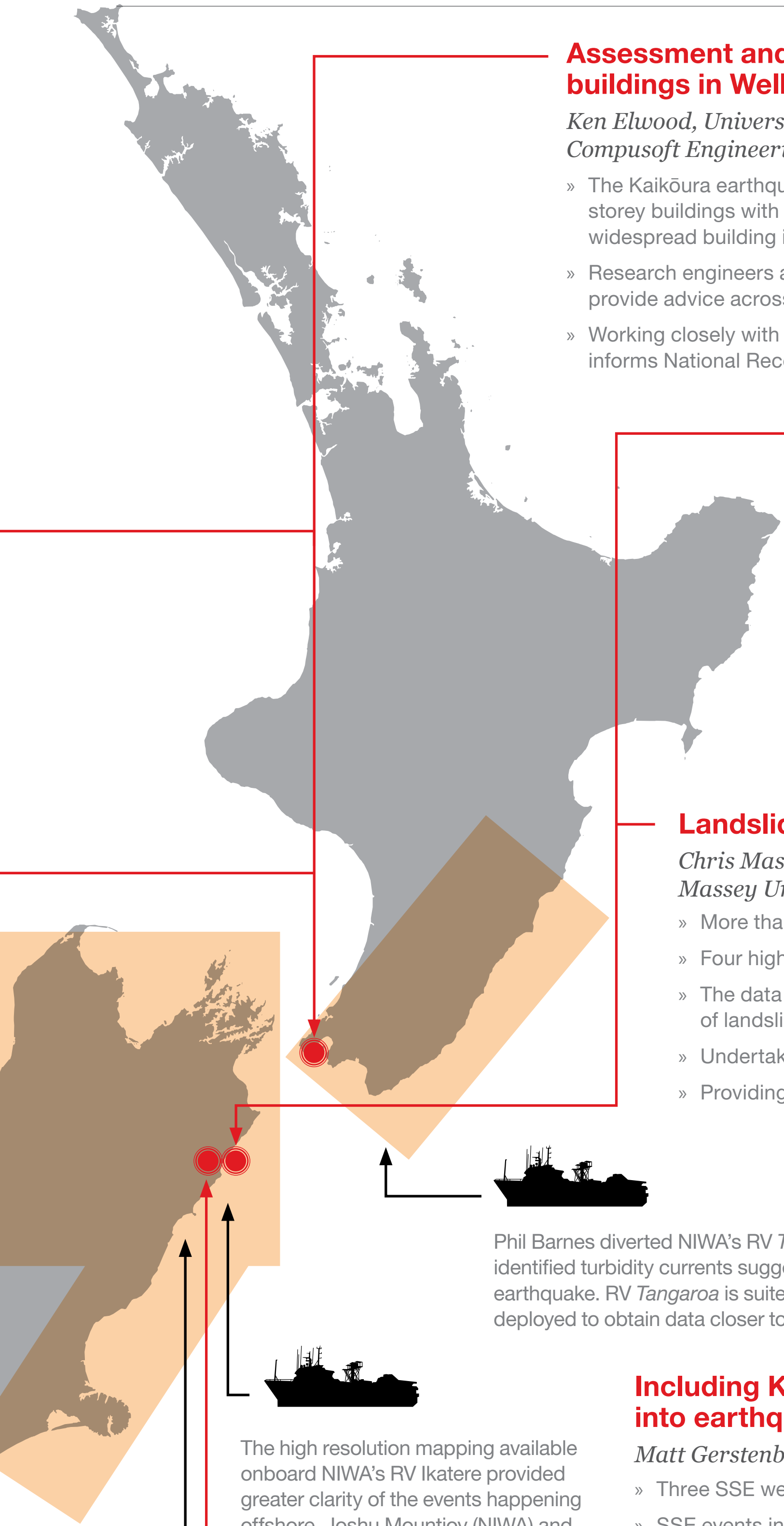
- Sub-surface geology influences how a building responds to earthquake ground shaking, and determines the subsoil site class.
- Five site classes have been defined in NZ standard 1170.5, these range from ‘strong rock’ to ‘very soft soils’.
- The team will create updated, open-access maps for subsoil site class and site period for Wellington CBD, including areas where there is scant data.
- These outputs will be vital for engineering design, re-building, and new buildings, and important for the long-term economic outlooks for Wellington.

Post-seismic deformation following the Kaikōura Earthquake

Sigrun Hreinsdottir, GNS Science

- Land deformation continues after seismic events and is an important dataset to capture
- Data from GPS stations – both permanent and temporary following the Kaikōura earthquake - will contribute to understanding of:
  - how stress is transferred in the Earth’s crust
  - the likelihood of another earthquake and
  - future of seismic risk in the affected region.





Assessment and repair of existing concrete buildings in Wellington with precast floors

Ken Elwood, University of Auckland, University of Canterbury, Compusoft Engineering

- The Kaikōura earthquake resulted in extensive damage to concrete multi-storey buildings with precast floor systems, and was a key factor that led to widespread building inspections in the Wellington CBD and elsewhere
- Research engineers are working with practitioners to access damage data and provide advice across the sector
- Working closely with MBIE Building & Housing System Performance group and informs National Recovery.

Inventories of onshore surface ruptures and coastal uplift

Nicola Litchfield, GNS Science, University of Canterbury, University of Auckland, Victoria University, University of Otago

- The Kaikōura earthquake was unprecedented in having multiple onshore surface fault ruptures (at least 21) and extensive coastal uplift affecting more than 110 kilometres of coastline
- The research will document permanent ground deformation, inform future seismic hazard and risk scenarios, and land-use planning.

Landslide inventory and landslide dam assessments

Chris Massey, GNS Science, University of Canterbury, Massey University and NIWA

- More than 10,000 landslides with an area greater than $100m^2$
- Four high risk dams continue to be monitored
- The data will provide a key landslide inventory showing location, size and type of landslide
- Undertake landslide dam surveys and assessments, modelling and monitoring
- Providing advice to National Recovery authorities on ongoing hazards.

Phil Barnes diverted NIWA's RV *Tangaroa* to survey the seabed. Barnes and team identified turbidity currents suggestive of undersea landslides triggered by the earthquake. RV *Tangaroa* is suited for deeper water surveys; the RV *Ikatere* was deployed to obtain data closer to shore (See Mountjoy).

The high resolution mapping available onboard NIWA's RV Ikatere provided greater clarity of the events happening offshore. Joshu Mountjoy (NIWA) and team mapped the seafloor around the Kaikōura Canyon, and identified widespread submarine landslides. They mapped the offshore extension of the major faults, and identified the new Point Kean fault off the Kaikōura Peninsula.

Including Kaikōura-triggered slow slip earthquakes (SSE) into earthquake forecasts and seismic hazard estimates

Matt Gerstenberger, GNS Science

- Three SSE were triggered by the Kaikōura earthquake
- SSE events increase the potential for large earthquakes in central New Zealand
- This research will provide improved probabilistic estimates for the occurrence of large earthquakes, and will be immediately included in aftershock forecasts provided by GNS Science & GeoNet
- Research contributes to improved national hazard and risk assessments.

Understanding land damage at Mt Lyford to inform Hurunui District Council recovery

Robert Langridge, GNS Science, ECAN, Hurunui DC, EQC

- Evaluate extensive damage to land and properties
- Provide updated advice on seismic hazard for the region
- The research is contributing to National Recovery aims.

Aerial reconnaissance of Kaikōura landslides

AUCKLAND VOLCANIC FIELD AND GEOHERITAGE

by
JON PROCTER, KAROLY NEMETH, ILMARS GRAVIS & BOGLARKA NEMETH, MASSEY UNIVERSITY

UNESCO Geoparks are an initiative to identify and support Geoparks. Geoparks recognise the connection of communities to significant landscapes and geological sites, and their conservation or sustainable development value for education and tourism.

Geoparks inform about geoheritage and focus on the geological nature and value of a geosite. The values are factors such as scientific scale, scope and significance, and educational, research and aesthetic significance. Very little value is attributed to the cultural connections. In the South Pacific, geosites and their management mechanisms are somewhat underutilized, maybe because indigenous communities very rarely associate with the scientific community, and can view scientific methods as foreign to their own knowledge systems.

A New Zealand case study evaluated the Ihumātao Peninsula and the Otuataua Stonefields Historic Reserve as a unique unbroken example of human occupation and agricultural practices. The reserve has archaeological, historic and environmental significance linked to its geological heritage. The Ihumātao Peninsula landscape, once widespread on the Auckland Isthmus and densely populated by Māori communities, is one of the last remnants of this type of volcanic landscape where significant physical features remain as historical markers. Urbanization and industrialization continue to threaten these pieces of land contiguous with the Otuataua Stonefields Historic Reserve (OSHR).

The volcanic geoheritage values of the Ihumātao Peninsula were measured following standard geosite evaluation methods, and the values are comparable to other globally significant geosites. The methods applied are broad and captured fine detail, including cultural aspects showing that the Ihumātao Peninsula carries enough geoheritage value to justify raising its protection and preservation status, and utilizing it for future geotourism and geoeducation developments. This study shows that a holistic approach to geoheritage evaluation is the key to better understand the geoheritage value of geosites in a cultural and social framework.

Massey University is investigating methods to better identify geoheritage values and look at revitalising conservation efforts around New Zealand's geological reserves.

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Tuff deposits from Maungataketake eruption with logs exposed that were buried during the time of the eruption. Photo: Massey University.

Maungataketake, 1958. Whites Aviation (Ltd) Collection, Alexander Turnbull Library, National Library of New Zealand.

EDGECUMBE: RISKSCAPE POST-DISASTER FLOOD DAMAGE

by
**RYAN PAULIK, NIWA &
JULIA BECKER, GNS SCIENCE**

On the morning of 7 April 2017, the Rangitaiki River breached a stopbank at Edgecumbe. Over the next 48 hours, thousands of cubic metres of water flooded the township, damaging homes and displacing many of the township's residents.

Ryan Paulik (NIWA) surveys the flood damage.

A research team from NIWA and GNS Science travelled to Edgecumbe after the flood. The Edegecumbe flood data will be incorporated into vulnerability models that estimate building damage and financial loss from flood hazards. The team coordinated their plans with the emergency operation centre in the area and the data is being shared with local councils.

The NIWA team recorded water levels, building attributes and building component damage at 220 residential homes. Component damage was estimated at 20 to 70 percent of replacement cost for most buildings. Water levels measured inside buildings were up to 1.1 m with particle board flooring being a key contributor to damage observed in most homes surveyed. In addition, high flood-flow velocities caused foundation failures for homes immediately opposite the stopbank breach site. A hydraulic model using RTK (Real Time Kinematic satellite navigation) GPS was included in our survey of ground and water levels. The modelled flow depths and velocities of the water that inundated these homes will help to better understand the conditions that single storey residential buildings may experience in causing foundation failures leading to complete building replacement.

The damage survey information has enabled NIWA to update residential building flood vulnerability functions in the RiskScape tool. RiskScape loss models can support flood risk management decisions, such as the cost-benefit of raising stopbank heights or floor level heights in buildings to reduce building damage in a flood event. RiskScape has estimated building repair and disruption costs of NZD$19.6m for the 220 homes surveyed, just under NZD$90,000 per home. This information will assist local authorities with recovery and future flood mitigation activities for Edgecumbe.

The social science team from GNS Science undertook a questionnaire with residents about the warnings they received before the stopbank flooding occurred. Prior to the breach, some residents were aware that flooding might be an issue given the rain that had occurred several days previously. However, others were unaware of the flood risk and were confused by the fact that on the morning of the breach it was a sunny day, and thus flooding had not crossed their minds. Most residents living near the stopbank breach received only a short (10-15 minute) warning, or no warning at all before the stopbank breached. Some people were quickly asked to evacuate by emergency services before floodwaters reached them, whilst others were caught in the floodwaters as they attempted to evacuate. There was little or no time to collect belongings or pets, or warn vulnerable residents (e.g. elderly or disabled) in the affected area. The speed of the flooding, the limited warning, the damage experienced, and the displacement of residents from their homes left many feeling unsettled and distressed. This understanding of how events unfolded in Edgecumbe can help provide advice on how to more effectively plan for future similar emergencies.

Residential building repair costs. Data: RiskScape.

Interior house damage. Source: NIWA

The research team entered the flood area with ethical approval and with the permission of the local council.

The Edgecumbe Team: Ryan Paulik, Kate Crowley, Shaun Williams, Graeme Smart and Jochen Bind (NIWA); Julia Becker and Luci Swatton (GNS Science)

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RiskScape

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CYCLONE COOK SENDS NHRP TEAM TO TAURANGA

by
JOHN MONTGOMERY, UNIVERSITY OF WAIKATO

As ex-tropical cyclone Cook bore down on New Zealand on 12 April, staff and students from the University of Waikato (UoW) and NIWA went into quick-response mode. The impending cyclone Cook was forecast to reach Tauranga the following evening and NIWA's upgraded red-alert tide calendar told us at a glance that the storm might coincide with a high spring tide. The projected high winds and low atmospheric pressure, combined with the high tide, had the potential to produce one of the highest storm-tides on record within Tauranga Harbour.

A quick discussion between Dr Scott Stephens (NIWA), Dr Karin Bryan and PhD student John Montgomery (UoW) was followed by John driving to Tauranga that afternoon to deploy four water-level sensors in shallow upper reaches of the Harbour, after UoW technicians scrambled to locate and programme the instruments. Scott contacted Peter Blackwood and Mark Ivamy at the Bay of Plenty Regional Council. Peter organised permission to deploy the instruments at short notice under the existing state of emergency in the area. Scott located additional sensors late Wednesday and several of the instruments were capable of measuring waves in addition to water level, which could provide valuable information on the importance of waves to coastal flooding and allow for better predictions in the future.

On Thursday, John and a NIWA surveyor went back to Tauranga to deploy the equipment, while the storm was already impacting the region. Fortunately for the people of Tauranga, the storm moved more quickly than expected, and the storm surge peaked about three hours before high tide. Additionally, the storm tracked further east than forecast, and this, along with its rapid movement, caused much less wind-driven surge than predicted. The timing and speed of the storm allowed Tauranga to sidestep a potentially devastating event.

During this time, seven pressure sensors were deployed in the Tauranga estuary. The data from these sensors showed that the water level varied by almost 25 cm in the estuary. The two locations with the highest water level were Pahoia Domain and Ariki point. This information, plus data from longer-term deployments in the Harbour, will be further analysed by John during his PhD.

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ETHICAL GUIDELINES FOR RESEARCHERS IN POST-DISASTER ZONES

by
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Following the onset of the Kaikōura earthquakes on 14 November 2016, several large New Zealand research programmes and organisations worked together to provide research support to response organisations.

The Natural Hazards Research Platform (NHRP) was mandated to coordinate this support, and did so in collaboration with QuakeCoRE and the Resilience to Nature's Challenge (RNC) research programmes. The rapid development of co-branded ethical guidelines over the first few days relied heavily on this working relationship.

A key lesson from the science response to the 2010-11 Canterbury Earthquake Sequence was that research activity posed a heightened ethical risk, irrespective of discipline. Minimising research demands on coordinating agencies and impacted communities would rely on raising awareness of this heightened risk among both researchers and non-researchers in the impacted region.

With these concerns in mind, the NHRP arranged ethical briefings for groups of researchers involved in immediate assessments on behalf of the science response. On the morning of 16 November, field scientists at a briefing at the University of Canterbury requested a one-page ethics reference guide to take into the field the following day. A single clearly worded page was designed to benefit both researchers and non-researchers in the region. It aimed to help researchers from all disciplines recognise the heightened risk, and listed three broad ethical principles that have been developed to reduce ethical risk in a related research context, and the way these principles might apply to the specific protocols/paperwork required by their own disciplines and institutions.

The one-pager also aimed to empower response agencies and community members when dealing with researchers, by clarifying that researchers must respect the rights of those in the region:

» to be informed of the risks research might pose to them, and to refuse to participate if they wish to do so for any reason,
» to benefit from research that involves them, and
» not to be subjected to an undue research burden, just because of their circumstances.

On 17 November, an early draft of the information sheet was taken into the field by the scientists who attended the briefing. At the same time the guidelines underwent rapid review by the Natural Hazards Social Science Panel (NHSSP). On 18 November this information sheet was:

» endorsed by the NHSSP, NHRP, QuakeCoRE and RNC
» posted on the Kaikōura Earthquake engineering clearinghouse website
» distributed by email and hard copy within the impacted region
» disseminated across New Zealand research networks, government agencies, and local and regional authorities in the impacted region, and
» distributed internationally through global organisations such as GFDRR and Understanding Risk network.

On 23 November, the New Zealand Health Research Council posted the information sheet on its website for the benefit of medical researchers thinking of working in the impacted region.

The rapid update of the guidelines - here and abroad - reflect a growing need. It is likely, however, that guidelines alone will not be enough. The Canterbury Earthquake experience suggests that research interest in Kaikōura and the North Canterbury region will continue to grow, posing the risk of additional ongoing stress for communities, agencies and service providers. A transparent and well-communicated research coordination and decision-making structure is likely to be required to manage this pressure. Ideally, this would be accessible online, explain the ethical risks, and include clear pathways that integrate research activity into recovery activities.

The Ethical Guidelines (above) are attached at the end of this issue.

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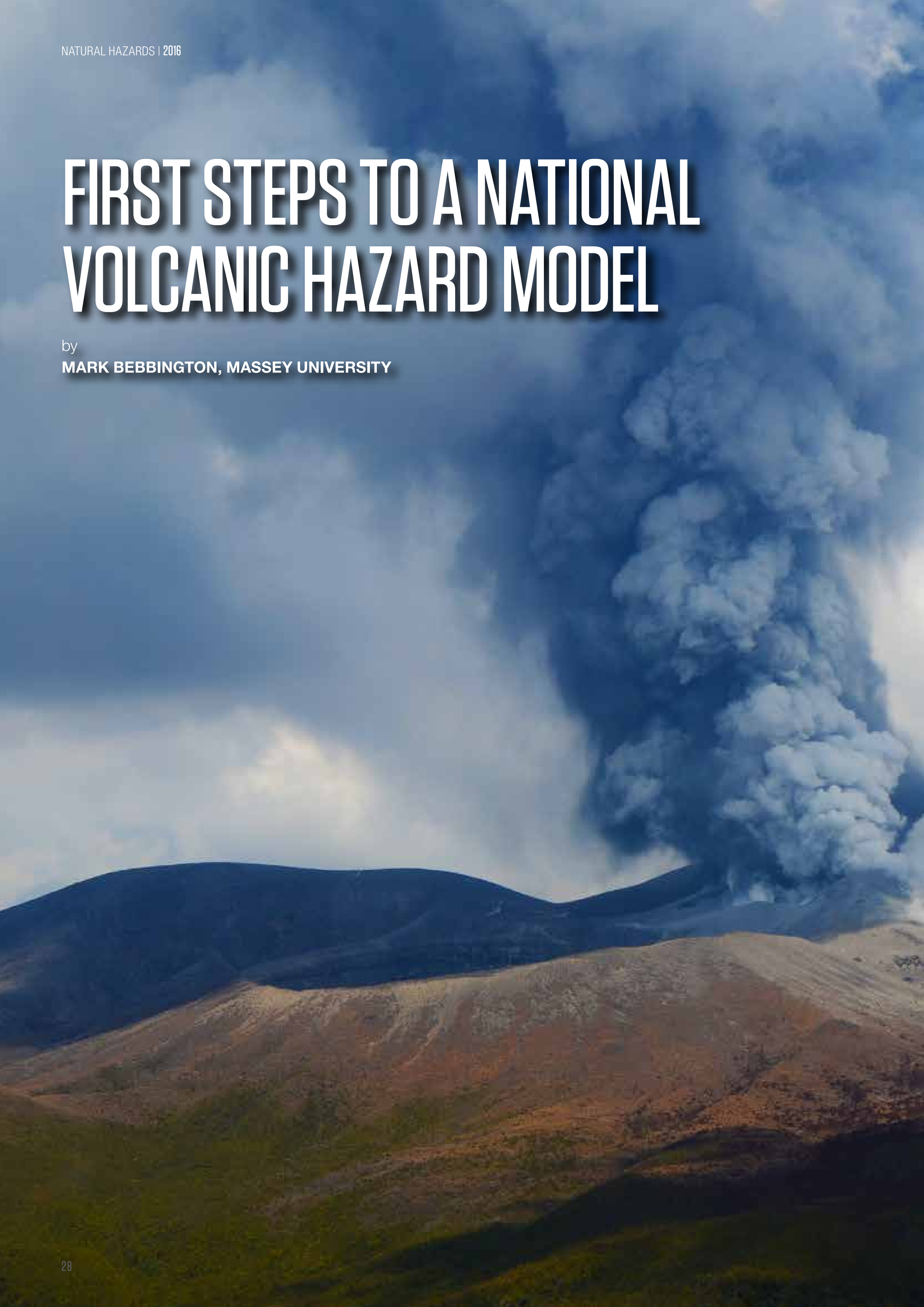

FIRST STEPS TO A NATIONAL VOLCANIC HAZARD MODEL

by
MARK BEBBINGTON, MASSEY UNIVERSITY

New Zealand has a world-class National Seismic Hazard Model, but earthquakes are not the only geological peril that threatens New Zealand. A team of researchers from Massey, Auckland and Otago universities, and GNS Science, have been working to scope out what the equivalent national-level model for volcanic hazard might look like, and to produce an initial first-order estimate of the 'when, where and how large' of the next eruption from a New Zealand volcano.

In both these endeavours the team have been assisted by a wide-range of scientists from GNS Science, Massey, Auckland, Victoria, Canterbury and Otago universities, through an expert elicitation process, and the development of a 'think-piece' describing the higher-level structure of a National Volcanic Hazard Model (NVHM).

National-level long-term eruption forecasts by expert elicitation

The initial step of a New Zealand volcanic hazard model is to quantify the likely timing, size and, in some cases, location of the next eruption from each possible volcanic centre. Incomplete and uneven records of past activity at various volcanoes have motivated an approach based on expert elicitation.

A total of 28 scientists shared their knowledge of the 12 volcanoes under study. They came up with estimates of the Volcanic Explosivity Index (VEI, used as a measure of eruption intensity) of the next eruption and, conditional on the VEI, the time to that eruption and its duration and, where appropriate, location.

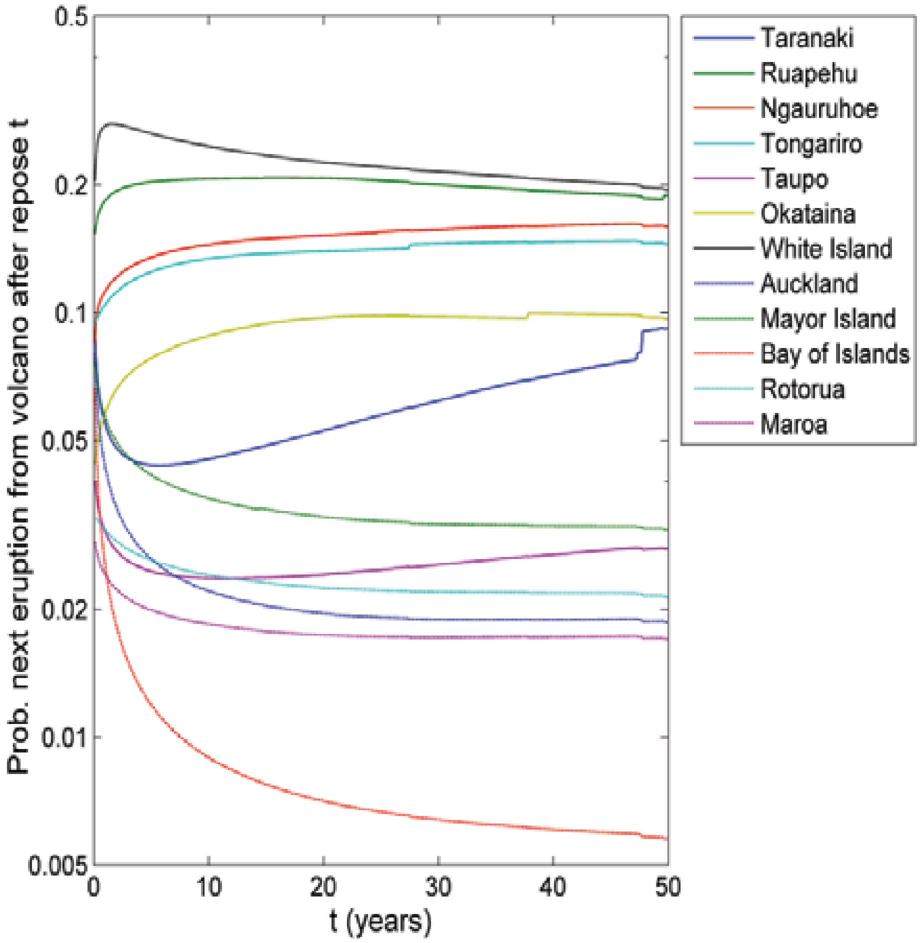

Fig 1. Elicited probability that a given volcano is the next to erupt, conditional on the length of time from present without an eruption from any volcano.

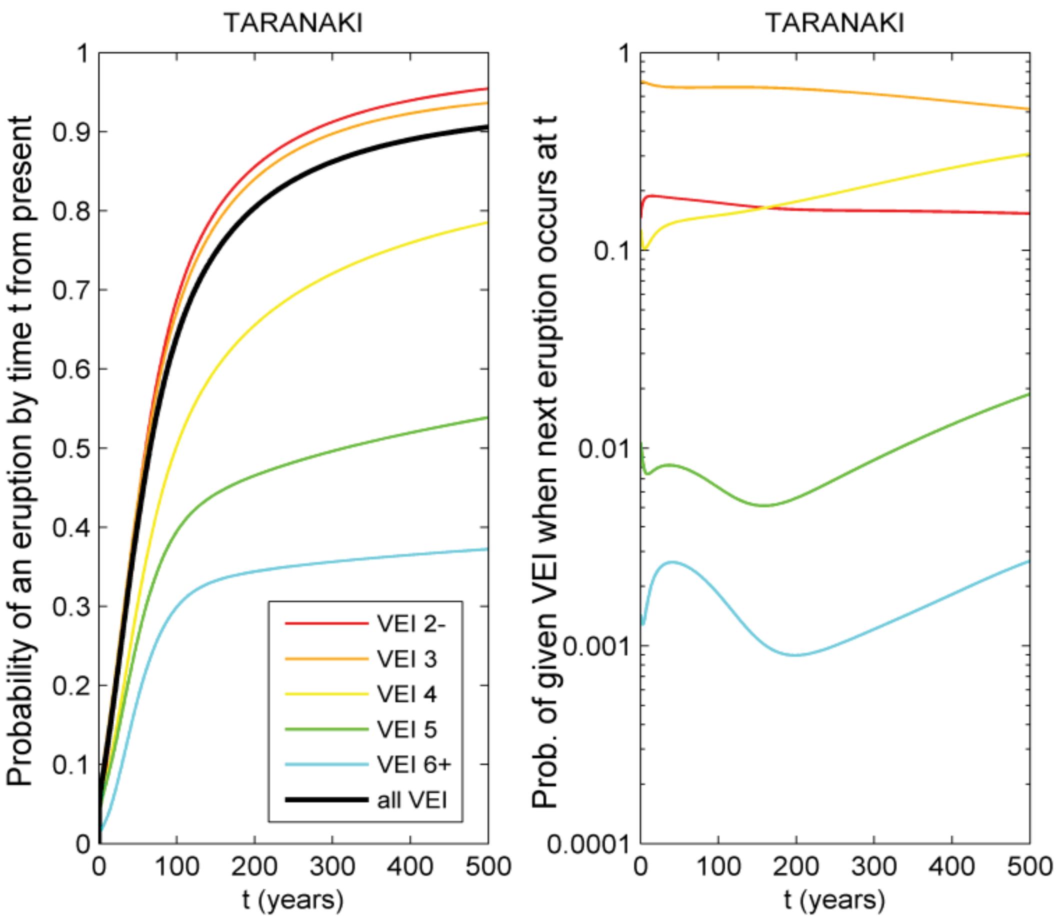

Fig 2. Elicited probability of an eruption occurring by a given time, conditional on it being of a specific VEI (left) to next eruption (left) and probability of the next eruption being of a given VEI, conditional on the time of the eruption (right). Time measured from present

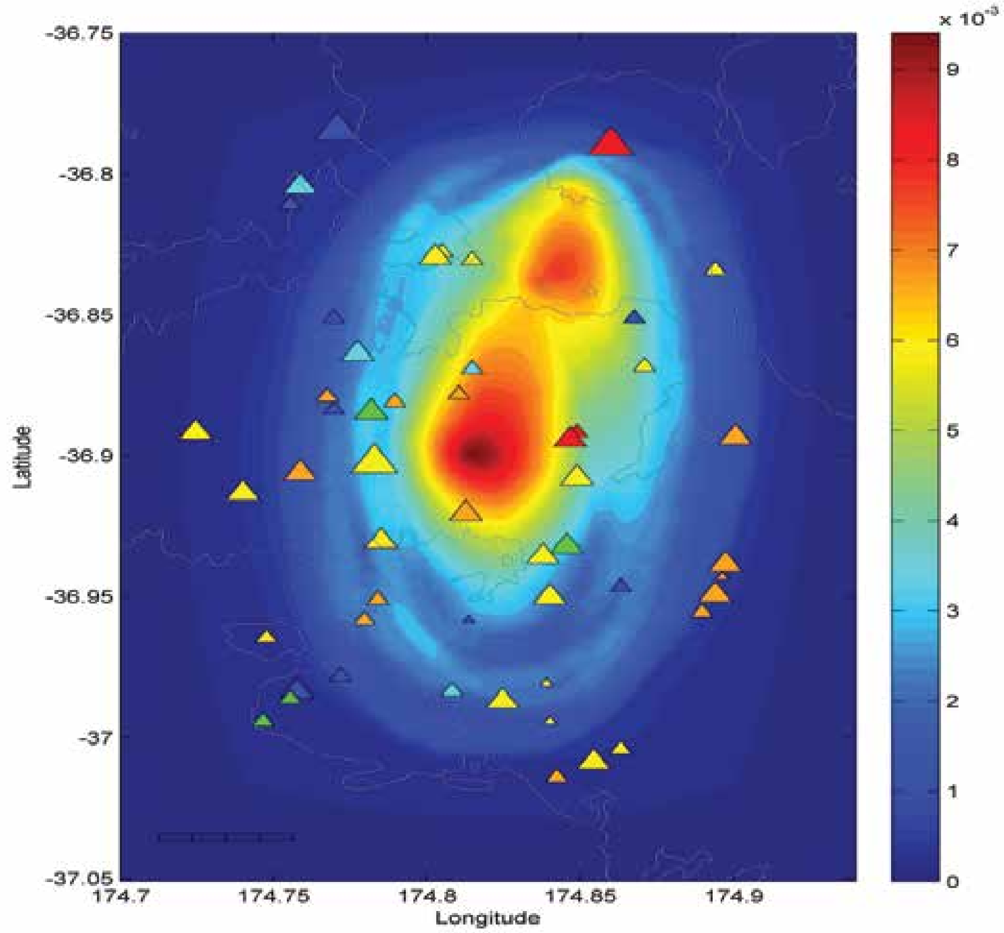

Fig 3. Elicited probability (per km^2) for location of next eruptive vent from the Auckland Volcanic Field. Triangles denote previous vents, with age on the heat scale (blue = oldest to red = youngest), and symbol size scaling with the eruption volume.

The expert opinions were combined using Cooke's classical method to arrive at a consensus hazard estimate. From this we can calculate the probability that a given volcano will be the next to erupt as a function of elapsed time without an eruption (Fig. 1).

The volcano considered most likely to erupt is White Island, which duly erupted just over 2 months after the elicitation workshop. The volcanic centres in Tongariro National Park are the other likely candidates. Because White Island and the Tongariro National Park volcanoes erupt relatively frequently, a long period without any eruptions makes Taupo and Taranaki more likely to be the next eruption.

With the exception of Taranaki, which is in an extended repose and expected to resume activity with a larger eruption (Fig. 2), the volcanoes of the central North Island had very similar elicited distributions for the VEI of a future eruption. The majority of the volcanoes exhibited a time-predictability factor, that is, larger eruptions become more likely with increasing repose in the elicited VEI distributions.

Elicited future vent locations for Taupo, Tongariro and Okataina strongly reflect the most recent eruptions. In Auckland, the elicited spatial distribution has picked out two 'empty' regions within the field (Fig. 3) where no events have previously occurred. There was no indication of dependence between eruption location and size.

The results will be presented at the next meeting of the New Zealand Volcanic Scientific Advisory Group.

Conceptual development of a national volcanic hazard model for New Zealand

A workshop involving volcanologists, statisticians, and hazards scientists was held in February 2016 to define the goals, challenges and next steps for developing a national probabilistic volcanic hazard model for New Zealand.

The goals centre around data, acceptance by the scientific community, civil defence and emergency management personnel and the general public, and utility for multi-hazard risk assessment. It should be open source, with a GIS front end. The challenges identified include: data quality, quantity and uncertainty; how multiple hazards should be measured and combined; how the results could inform building codes; defining default volcanic sources and hazard models; validation and updating.

The next immediate scientific steps were seen as developing new models for the emplacement of lavas across low topographies; agreeing on the most suitable model for the emplacement of pyroclastic density currents; and updating probabilistic ashfall models. As part of these objectives it is desirable to compare existing mapped volcanic deposits with results from hazard models, and to investigate the volume partitioning of volcanic eruptions among the various products such as tephra and lava. For more details see Stirling et al. (2017), Frontiers in Earth Science, https://doi.org/10.3389/feart.2017.00051.

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NATURAL HAZARDS IN 2016

A brief snapshot of the main events.

EARTHQUAKES

Geonet recorded 32,828 earthquakes in New Zealand in 2016 – more than the annual average, which is around 20,000. In 2016 there were 142 earthquakes recorded with magnitudes greater than 5.

The M5.7 Valentine's Day 2016 earthquake was located 2 kilometres offshore of Christchurch at a depth of 8 km, with MMI 8 impact experienced in central Christchurch, and a peak ground acceleration of 0.4g, leading to some liquefaction in some areas around the city

On 2 September, a M7.1 earthquake occurred more than 100 kilometres north-east of East Cape, and generated a small tsunami (30 cm), which was recorded on East Cape and Great Barrier Island tsunami gauges.

On 14 November, the M7.8 Kaikōura earthquake ruptured across numerous faults in the North Canterbury and Marlborough Fault areas and raised the seabed off the Kaikōura coast. Ground shaking reached over MMI 8 (severe) near the fault rupture, with a peak ground acceleration of at least 1.3g. Wellington city experienced up to MMI 7, and with peak ground acceleration exceeding 0.2g in parts of the CBD, with long period energy leading to building damage. This earthquake also triggered slow-slip events further north offshore of Hawke's Bay and Porangahau. More than 6,000 aftershocks followed the initial mainshock.

TSUNAMI

This was an unusually busy year for tsunami, especially from local sources. The East Cape earthquake generated a small tsunami, followed later in the year by the Kaikōura earthquake-tsunami sequence.

The Kaikōura earthquake caused a moderate tsunami around the central east coast of New Zealand. The largest recorded wave was around 2.5 metres (zero to peak) measured at the Kaikōura tsunami gauge. At Oaro and Goose Bay, from deposits of marine debris, the tsunami run-up heights along the beach were between 4.5 and 6.9 metres above sea level and the river valley in Oaro was inundated more than 200 metres inland. Further south at Little Pigeon Bay on the northern side of Banks Peninsula, the tsunami excited the resonant period of the bay. The valley was inundated up to 140 metres inland with a run-up height of 3.2 metres above sea level and severely damaged a historic farm cottage on low-lying ground at the head of the bay.

On 9 December, a tsunami potential threat advisory was issued following the M7.8 Solomon Islands earthquake, however no significant impact occurred.

VOLCANIC HAZARDS

During the year we had one volcanic eruption. On 27 April 2016, the Volcanic Alert Level was raised from 1 to 3 for White Island (Whakaari) after an explosive eruption removed the small crater lake and excavated the crater floor. A destructive surge passed over the main crater floor. Minor volcanic ash emissions followed from vents on the 2012 lava dome. The Aviation Colour Code was raised from Green to Orange. GeoNet reported the "volcano is exhibiting heightened unrest with increased likelihood of eruption" for several months following this event.

Ruapehu was heating up over the first half of 2016 with the Volcanic Alert level raised to 2 and the Aviation Colour Code changed from Green to Yellow. Ruapehu has since cooled down again and remains at Volcanic Alert Level 1 and Aviation Colour Code Green.

LOW RAIN & DROUGHT

Partly due to the strong El Niño event the of late 2015-early 2016 period, below average rainfall for some eastern parts of New Zealand was reflected in soil moisture levels during the year. Below normal soil moisture levels prevailed in eastern parts of north Canterbury and eastern Wairarapa for much of the year. This meant that the prolonged drought conditions of 2015 and associated low soil moisture in eastern parts of the South Island (Marlborough, Canterbury, and parts of Otago (Central Otago, Dunedin and Waitaki)) persisted for most of 2016. The official Ministry for Primary Industries (MPI) drought declaration remained in effect until December 2016 for some places.

LANDSLIDES

Landslides were dominated by the M7.8 Kaikōura earthquake, which triggered tens of thousands of landslides, over an area of about 10,000 km^2 from North Canterbury to Marlborough. Hundreds of large (100,000 – 500,000 m^3) landslides disrupted both SH1 and SIMT railway both north and south of Kaikōura, isolating the town for several weeks. It is expected to cost $2 billion NZD and take a year to repair and reinstate SH1 and the rail line. Landslides inland dammed river valleys, creating 196 landslide-dammed lakes. These were identified and monitored by GNS Science in the days and weeks following the earthquake, as sudden breaching of the dams posed the greatest risk to society and infrastructure. GNS Science is compiling a world-class inventory of the landslides triggered by the earthquake, to understand the relationships between fault rupture, earthquake shaking, and geologic and topographic controls on landslide triggering. Other major landslide events in the past year include several cyclones that bought heavy rain to the northern and central regions. In March, Cyclone Debbie triggered landslides in Auckland, Coromandel, and the Bay of Plenty, damaging several houses and causing many to be evacuated. In April, the remnants of Cyclone Debbie caused widespread flooding and landslides over much of the North Island, and was followed closely by Cyclone Cook which caused more landslides in areas already impacted.

SNOW, HAIL AND ELECTRIC STORMS

On 16 May, 30,000 lightning strikes were recorded across the country as an active cold front crossed the country and on 24 May central NZ recorded 18,000 lightning strikes and some power cuts. On 22 May, 38 people on a 4WD outing were trapped on the Old Man range near Roxburgh and had to be rescued. From 5-8 August, a significant snow event hit the central and eastern North Island. The Napier-Taupo highway and the Desert Road section of SH1 were closed and snow and ice brought down 200 power poles, and overloaded high-voltage transmission lines serving the Hawke's Bay region, causing power cuts to around 100,000 people. On 7 and 14 October, several orchards near Nelson and Motueka suffered damage from hail and on 3 November, Waimate was hit by hail with accumulations to depths of around 7 cm.

WIND & TORNADOES

In 2016, the number of damaging high wind and tornado events was similar to 2015 and considerably lower than what had been experienced in the 5 years prior. However, there were a few damaging events with power disruptions in Auckland (22-24 March, 27 June, and 26 August), Canterbury and Wellington (12 May and 7-8 September). Weak tornadoes were reported in Waikato, West Coast, Bay of Plenty, Taranaki, and Kapiti Coast.

HEAVY RAIN & FLOOD

In 2016 the most significant flood events were in the West Coast and Tasman Districts (23-24 March, $30M), Wellington region (15 November, $9M and 5 May, $4M), and Auckland (29 June, $2.4M). On 24 March, a state of emergency was declared on the West Coast and 200 people were evacuated in Franz Josef after the Waihou river burst its banks. Parts of the Tasman District were also inundated affecting orchards and crops during harvest. On 15 November, heavy rain closed SH1 and SH2 north of Wellington and power was lost to 500 homes in Pukerua Bay and parts of Porirua. Overall, the national total damage (insured losses) from severe weather events in 2016 in was estimated to be $53M. One of New Zealand's rainiest locations, Milford Sound, recorded 9,259 mm of rain in 2016, its wettest year since records began in 1929.

COASTAL HAZARDS

On 24 July strong NW winds contributed to stormy seas. These stormy seas, in combination with high tides, hammered coastal parts of Porirua and the Kapiti Coast, closing several roads as waves washed over them. The massive waves caused considerable coastal erosion on Kapiti beaches and a 10 metre seawall was washed away at Plimmerton.

For more info, visit –

GeoNet: www.geonet.org.nz

NIWA's National Climate Summaries: www.niwa.co.nz/climate/summaries

National Science Challenges
RESILIENCE TO NATURE'S CHALLENGES
Kia manawaroa – Ngā Ākina o Te Ao Tūroa

Information Sheet:
Ethical Guidelines For Post-Disaster Research

Research activity in disaster-impacted regions incurs ethical risk

After disasters, people converge into the impacted area, in order to support response and recovery, and to conduct research. Their presence and activities, however, risk putting pressure on scarce resources and interfering with response operations. Interactions with community members can exacerbate stress (IAVCEI 1999; Citraningtyas 2010).

Researcher convergence, and the effects of the disaster, mean that all research activity in disaster zones, irrespective of discipline, carries heightened ethical risk. The field of ethics concerns the way people relate to others, and the identification of ethical 'bottom lines.' Decisions and actions, for example, should not benefit the decider/actor at the expense of others, increase harm to others, or violate human rights (Werhane 1999).

After disasters, defer data-gathering, unless in support of the response operation

As a rule, data gathering should be deferred during response. Researchers should refrain from entering or engaging with impacted communities, unless required to do so in support of the response. Researchers supporting the response should take measures to minimise pressure on scarce resources, demands on local officials, and stress among locals as a result of their research activities.

Guidelines for human interaction when conducting research

The Belmont Report provides three ethical principles or bottom lines designed to minimise the risk of harm to human research subjects. This makes them useful for researchers from all disciplines gathering data in disaster zones, where research activity has the potential to increase harm to disaster-affected individuals and communities.

1. **The RESPECT FOR PERSONS/INFORMED CONSENT principle:** Requires that people are considered capable of making informed decisions. People have the fundamental human right to be fully informed about research that carries any risk to them, and they have the right to refuse to be involved. *(Belmont Report 1979)*

After disasters, respect and prioritise the needs of locals and the response operation

- **Inform response agencies** about data gathering activity
- **Wear and carry clear identification** – include name, organisation and contact details
- **Before gathering data** on private property
- **Contact the owner, inform them** (what data, how will it be gathered, what will it be used for, potential risks to owner)
- **Request consent to gather data**
- **Respect and defer to the wishes of officials and owners** – 'take no for an answer.'
- **Record interactions** with officials/owners, including written consent to gather data

2. **The BENEFICENCE principle:** Requires that research does no harm and also provides benefits to those it directly impacts.

After disasters, ensure human interactions do not inadvertently increase harm

- **Clearly communicate identified sources of risk to officials**
- **Ensure interactions do not undermine the response;** refer locals seeking information to relevant officials
- **Ensure interactions do not increase stress;** be sensitive to local emotions and needs
- **Restrain enthusiasm for data;** it can be interpreted as insensitivity
- **Avoid creating unnecessary anxiety by speculating** to locals

After disasters, provide research benefits to officials and impacted communities

- **Make data available for response purposes**
- **Support officials with advice**, if they request it
- **Ensure that data gathered on private property remains available to the owner** (it belongs to them under NZ law)

3. **The DISTRIBUTIVE JUSTICE principle:** Requires that research burdens and benefits are fairly distributed. 'Unjust' social patterns should not be exacerbated by additional research burdens. One social group should not carry the burden of research that benefits another group. Populations should not incur a research burden just because of their situation.

After disasters, minimise the footprint & impact of data gathering

- **Coordinate research activity, and share data**, to minimise researcher numbers/activities in the disaster impacted area
- **Ensure research teams are resource-independent** (food/water/tents/fuel etc); do not increase the pressure on scarce local resources

Resilience to Nature's Challenge

http://resiliencechallenge.nz/

The Resilience Challenge aims to enhance New Zealand's resilience to natural hazards. The Challenge is a partnership of researchers from all NZ universities, four CRIs and several other agencies working together with councils, communities, businesses, iwi, and central government units. The focus is on developing resilience solutions to our differing environments, including specialist case studies in urban, rural, Māori and coastal settings.

The Resilience Challenge is a National Science Challenge funded by the Ministry of Business, Innovation and Employment.

Quake Core

http://www.quakecore.nz/

QuakeCoRE will transform New Zealand's earthquake resilience through innovative world-class research, education of the next-generation, and deep national and international collaborations. QuakeCore's multi-disciplinary research and stakeholder engagement will lead to policy and practice developments to improve how communities recover and thrive after major earthquakes.

QuakeCoRE is funded by the Tertiary Education Commission.


NATURAL
HAZARDS
RESEARCH PLATFORM