NATURAL HAZARDS 2017

Volcanic Hazard Advice: NZ & Abroad

High Impact Weather Research

Kaikōura Earthquake Research

NATURAL HAZARDS RESEARCH PLATFORM

RESILIENCE TO NATURE'S CHALLENGES

Kia manawaroa – Ngā Ākina o Te Ao Tūroa

National SCIENCE Challenges

The 50th Anniversary of the 1968 Inangahua Earthquake - Remembering the lessons for future generations. Photo: Lloyd Homer, GNS Science.

50th Anniversary of the Inangahua earthquake.
l-r: Aly Curd, Helen McCracken, Denise Blake, Simon Nathan, Sophie Orchiston, Caroline Orchiston, Emily Campbell, Hamish Campbell.
Photo: David Johnston, GNS Science.

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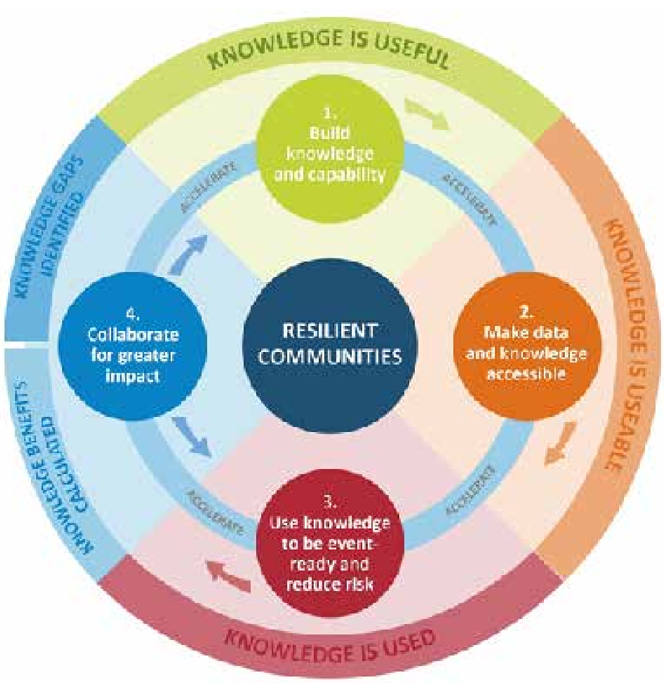


Partnership is at the heart of Science for Resilience Action.

New Zealand has very high exposure to natural hazards with potential to seriously disrupt the national economy and create long-term distress for households and communities. We have been reminded of this confronting reality by the scale of the losses and complexity of impacts from the 2010–11 Canterbury earthquakes, the 2016 Kaikōura earthquake, and recent extreme weather events that overwhelmed several coastal communities. Such events have revealed a gap between communities' expectations of the resilience of their land and buildings before a disaster, and the severe reality of the disaster experience.

As a country, we cannot rely on transferring (through reinsurance) natural hazard risk as our main disaster recovery tool, although it will always remain essential. However, neither can we accept unconstrained increases in our exposure and vulnerability to disaster.

New Zealand needs an integrated approach to managing disaster risk that considers the costs and benefits of all potential risk management options, including avoiding or retreating from high hazard areas and designing for improved disaster resilience.

Domestic and overseas disasters regularly remind us that relatively small investments beforehand in enhanced design to reduce damage to buildings and infrastructure, and land-use planning that avoids the worst hazard exposure, can result in significant savings in avoided losses. Risk reduction investment also provides benefits in faster community and household recovery times and reduced social misery.

As a nation, the challenge is to lift our understanding of the consequences of disaster risks until they are embedded in our policy settings and decision-making by all parts of society. Such action will require transformative efforts to bring together the scientific knowledge and experience to support community discussions about the difficult choices we may have to make. Our choices are wider if we make them before disasters happen.

The Earthquake Commission (EQC) is in a unique position to work across the science, insurance, and government sectors, integrating the sectors to influence better outcomes from the natural hazard management system. EQC has been undertaking a major review of its research and education investment approach that reflects our ambition to take a stronger role in risk reduction action to enhance national disaster resilience.

The approach is driven by the 'value chain' of investing in useful science data that is made useable through integration, translation and modelling, so policy-makers, planners, engineers and householders can use the subsequent information. The framework supports the case for:

- Enhancing New Zealand's knowledge of natural hazards and human behaviour related to disaster risk decisions;
- Building national capability for modelling economic and social consequences of natural hazards;
- Applying such models to inform operational readiness, risk reduction policy and infrastructure development choices.

Implementation requires that we must develop strong, collaborative relationships that cross the boundaries between science, policy, and practice within the natural hazard management system. These partnerships will deliver science that has the ability to influence a reduction in the country's natural hazard risk profile, resulting in an increased resilience of New Zealand's built environment. The Natural Hazards Research Platform has been an essential feature of the system in this regard, bringing together researchers from different disciplines and organisations in support of the strategic challenges identified by policy makers and practitioners. As the Platform looks to close out its successful 10 years of collaboration, EQC looks forward to the successful legacy continuing into phase two of the Resilience Challenge.

Dr Richard Smith
New Zealand Earthquake Commission

NEW OPPORTUNITIES ON THE HORIZON!

Welcome to our first joint publication from the Natural Hazards Research Platform and Resilience to Nature's Challenges.

We're pleased to be able to share with you highlights from the past year. In this issue, we'll update you on programmes that are exploring our resilience to natural hazards, enhancing our understanding of geological and weather processes, and improving the functions of our lifelines and built environment.

From the South Island, we'll update you on research that is helping Franz Josef locals understand the risks they face from natural hazards, as well as research that is enhancing preparedness, coordination and recovery in the event of an Alpine Fault earthquake. Both of these programmes are underpinned by research contributions from multiple teams working with local stakeholders, and it is great to see it all come together as a package of research that is 'useful, useable and used.' We'll also update you with the latest from volcanic hazards researchers, including advances in eruption modelling and forecasting, evacuation strategies for one of our busiest cities, and how New Zealand volcanic expertise is used overseas.

Research from the 2016 Mw7.8 Kaikōura earthquake is still very important to New Zealand but also overseas, especially in high seismic zones. This issue provides an update on the earthquake's impacts on Wellington buildings, liquefaction impacts on reclaimed land, and how ground shaking is influenced by subsoil properties. Many of the Kaikōura research outputs have been published in a special issue of the *Bulletin of the Seismological Society of America*. These papers, most led by New Zealand scientists, feature numerous authors from multiple countries all working together to understand the complexity of the event. This sharing of information - in country or across borders – helps us learn from key events and benefits everyone involved.

Natural Hazards Research Platform & Resilience to Nature's Challenges.
l-r: Ali Rogers, Maureen Coomer, Anne-Marie Rowe, Shane Cronin, and Catherine Pinal.

As the Natural Hazards Platform draws to a close (by 2019), we have the exciting opportunity to look forward to with the Platform becoming embedded in the Resilience Challenge. The combination of these two research entities will provide a strong base of expertise and resources. Currently, researchers are engaging with stakeholders to shape this next phase. We'd like to acknowledge all those who are contributing their time and effort towards identifying key research that will bring about a greater resilient future.

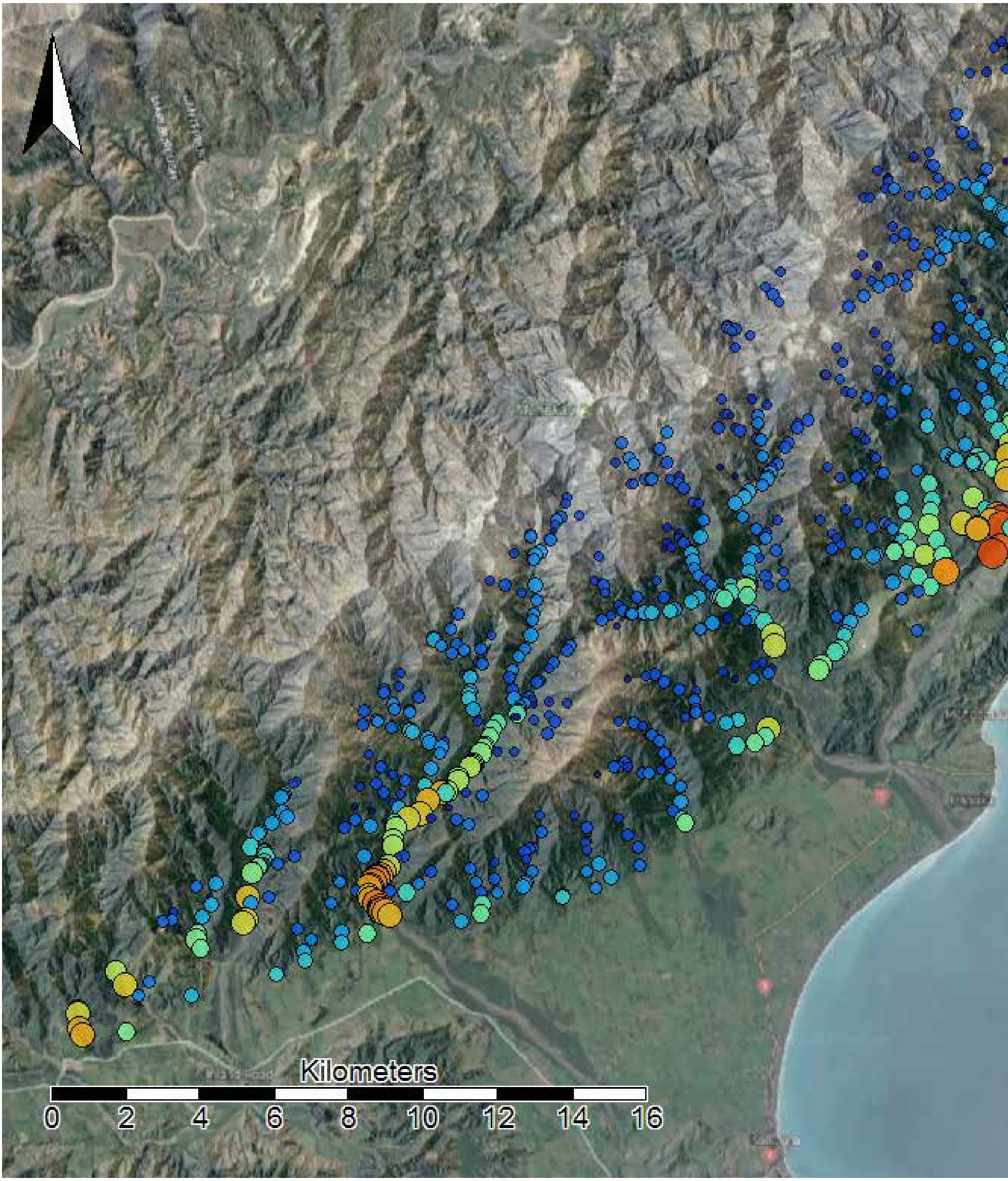
We hope you enjoy this issue of Natural Hazards and wish you all the best!

Natural Hazards Research Platform:

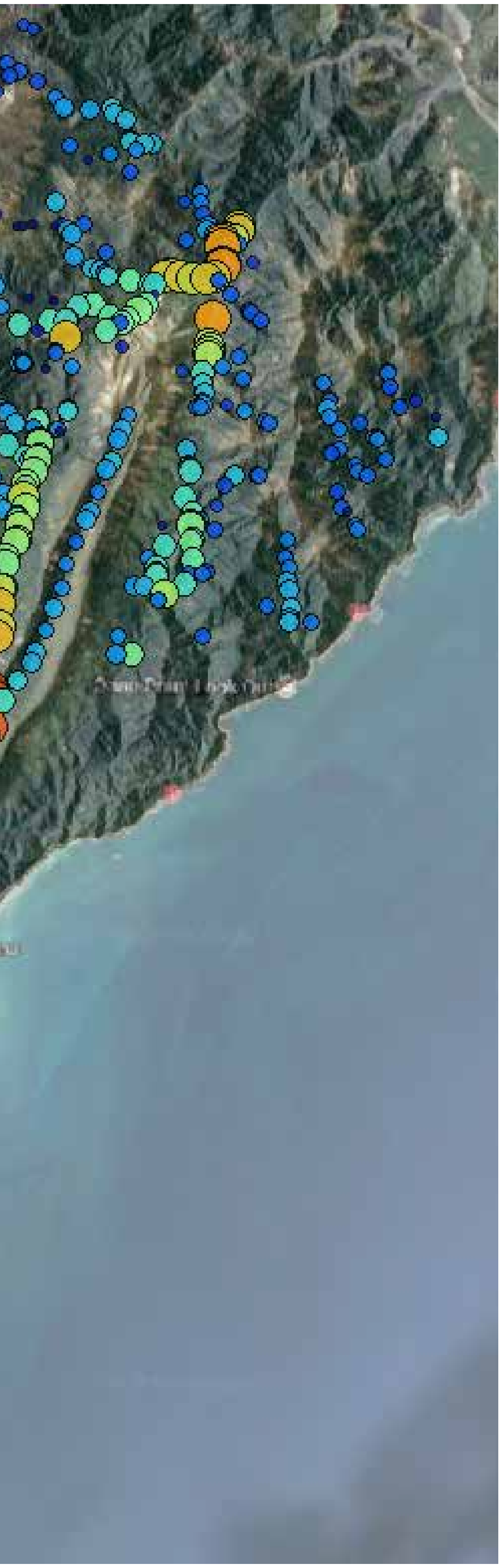
Catherine Pinal
Maureen Coomer

Resilience to Nature's Challenges:

Shane Cronin
Anne-Marie Rowe
Ali Rogers



An example of Alex Dunant's model prediction of potential peak flows from landslide dambreak floods north of Kaikōura.



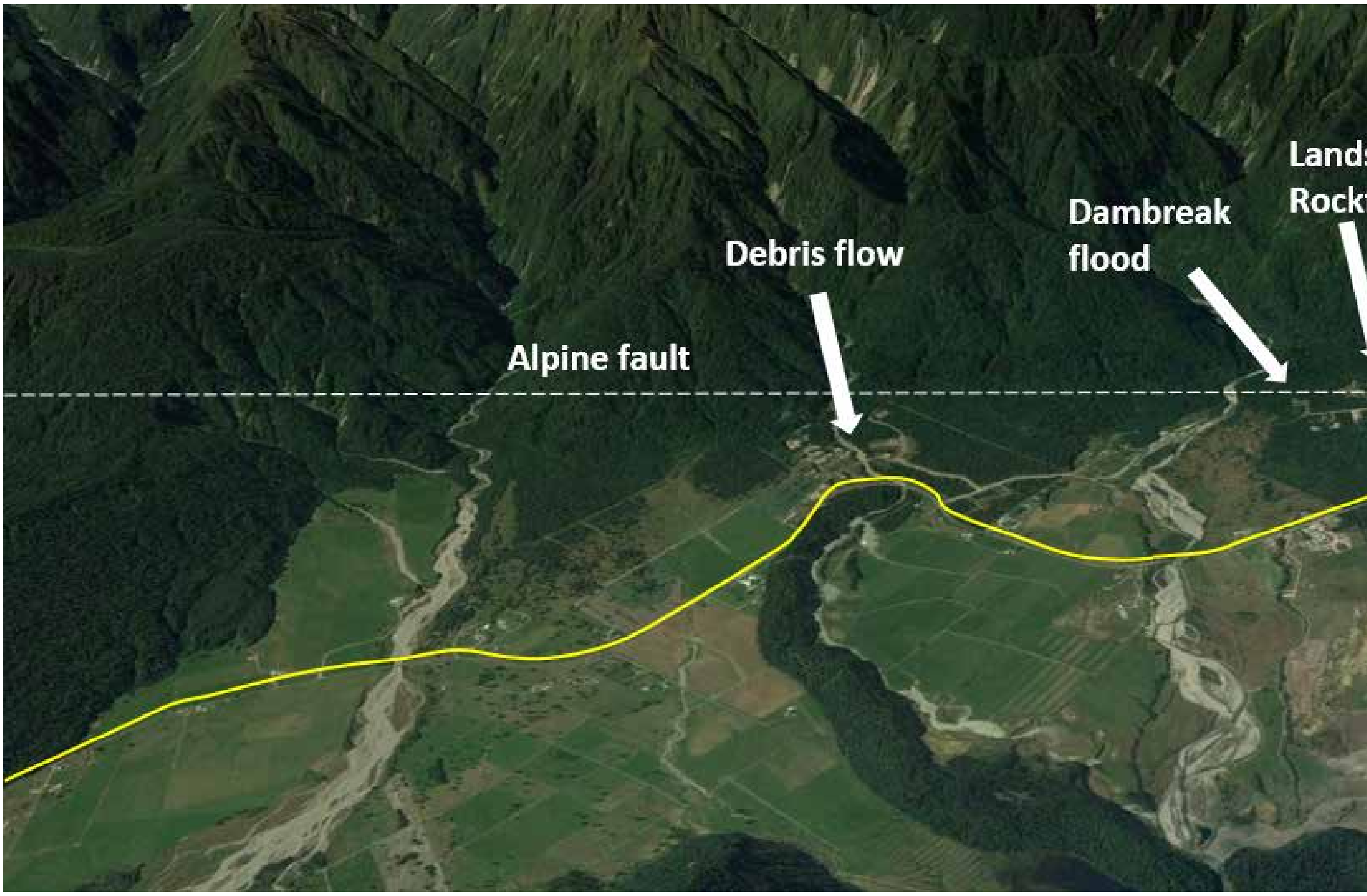
INCREASED DISASTER RESILIENCE AT FRANZ JOSEF

By
TIM DAVIES, MARK BEBBINGTON, KAT HORE, ALEX DUNANT, ALI DAVIES, AND TOM WILSON

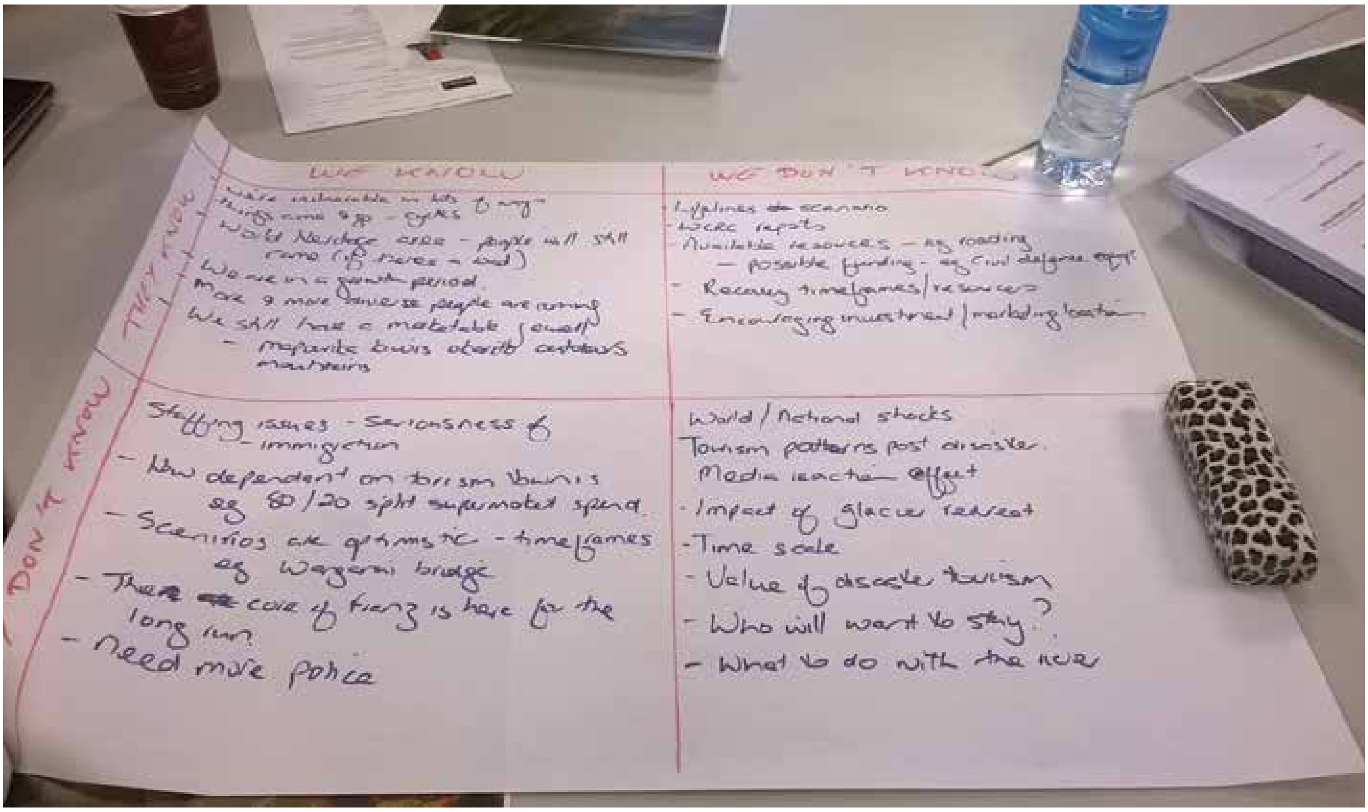
The Franz Josef Glacier township lies in one of the most beautiful and active landscapes in the world. It is a world-leading and rapidly-expanding tourist destination of national importance, with the tourism industry having overtaken traditional local occupations of farming and forestry. The extreme landscape activity threatens the township and community with the potential for a range of hazard events including earthquake, flood, landslide and rockfall, among others. The Franz Josef community is concerned about its long-term ability to live through, and prosper after, the next significant natural hazard event that strikes it.

A research team funded by the Resilience to Nature's Challenges Hazards Toolbox has been collating available natural hazard information and working with the Franz Josef community to better understand these hazards and the effects they may have. They have generated scenarios representing the impacts that these hazards – singly, in combination, or as a cascade – will have on the town's assets and on the regional lifelines. This can shed light on the functions of the community that allow it to survive commercially and socially.

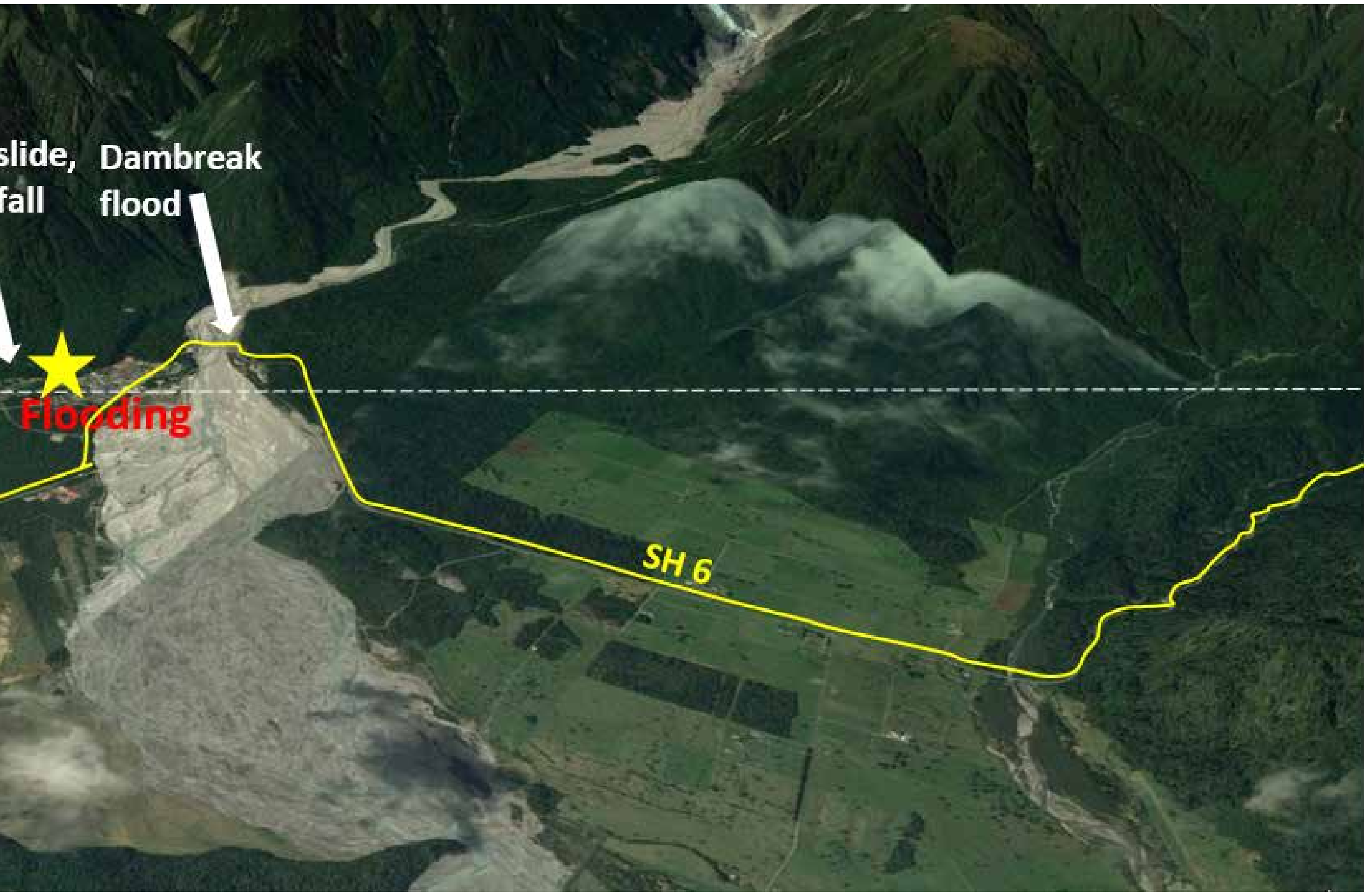
As a starting-point for understanding what is required to improve resilience, the team is focussing on ways in which the community can plan in advance to reduce and adapt to the impacts of severe hazard events. The impacts include loss of power, loss of communications, and loss of road access, all of which, especially if of long duration, would severely reduce the ability of the township to function.



Hazards the Franz Joseph community are vulnerable to.



Community output from working session.



The West Coast Regional Council asked environmental and engineering consultants Tonkin + Taylor to investigate the township's options for increasing its resilience to natural hazards. In late 2017 the company presented three options to the Franz Josef community that offered varying levels of resilience ranging from lower-cost options where the township stays where it is, to a higher cost option in which the entire township is moved from the high-risk area. The community is currently discussing these adaptation options. PhD researcher Kat Hore from The University of Auckland is living in the Franz Josef township for extended periods in order to understand how communities grapple with such significant decision-making processes.

The full combinations of natural hazard events that can impact Franz Josef are currently unknown, especially their ability to form 'hazard cascades'. Hazard cascades occur when, for example, an earthquake causes a major landslide that blocks a river to form a landslide dam. This dam can fail when it overtops, sending a 'dambreak flood' down the river to threaten communities already reeling from the earthquake. PhD student Alex Dunant at the University of Canterbury is developing a simulation model which will examine all possible combinations and cascades of hazards affecting all societal assets. This model is designed so that it can be applied not only locally, as at Franz Josef, but across much larger areas. This will enable the work to be linked to that of PhD student Ali Davies, who is investigating the resilience of regional infrastructure and its impacts on isolated communities like Franz Josef.

The Hazards Toolbox team works closely with the Franz Josef community, Regional and District Councils, Civil Defence Emergency Management Groups and lifelines organisations.

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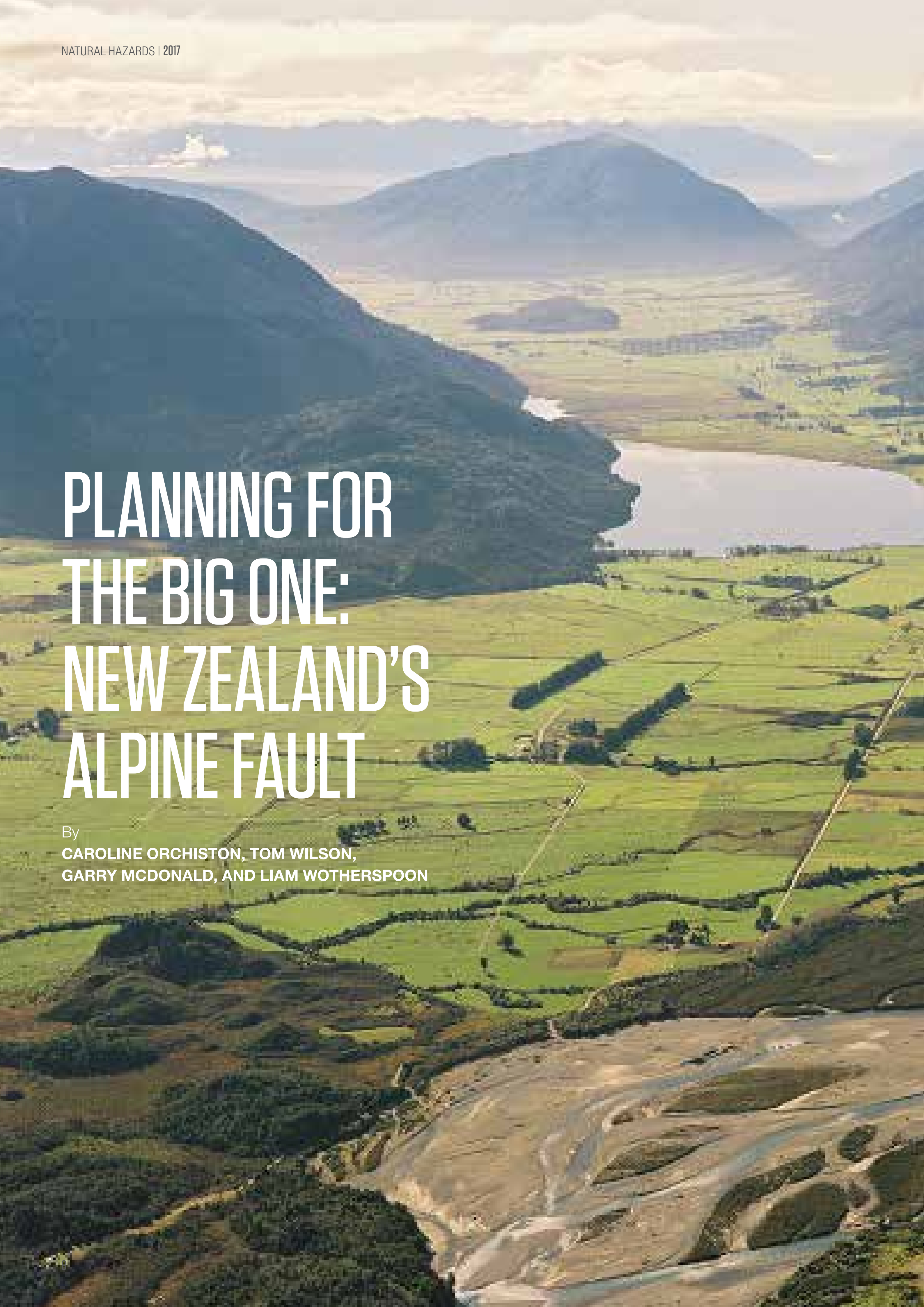

PLANNING FOR THE BIG ONE: NEW ZEALAND'S ALPINE FAULT

By
CAROLINE ORCHISTON, TOM WILSON, GARRY MCDONALD, AND LIAM WOTHERSPOON

The Alpine Fault, Lake Poerua and Taramakau River. Photo: Lloyd Homer, GNS Science.

The Alpine Fault is a major plate boundary fault running through the South Island, that has a long history of generating large earthquakes. The fault produces magnitude 8 earthquakes every c. 300 years, and the last one was in 1717 AD (301 years ago). A magnitude 8 earthquake on the Alpine Fault would widely impact the South Island and its effects would be felt across the rest of the country, so are we prepared for the next one?

Resilience to Nature's Challenges research teams are working with Civil Defence Emergency Management (CDEM) and lifelines agencies in the South Island to improve our understanding of the likely impacts of an Alpine Fault earthquake and to enhance the way we respond and recover.

The location of the Alpine Fault and plate movement.

The research teams are working in partnership with Project AF8, a South Island-wide Alpine Fault earthquake response planning initiative. The project, led by the six South Island CDEM groups and co-funded by the Ministry of Civil Defence and Emergency Management (MCDEM), aims to produce a cutting-edge scenario-based earthquake response plan informed by the latest research in earthquake science. The so-called South Island Alpine Fault earthquake response (SAFER) framework will improve the ability of South Island CDEM groups and their partner agencies to respond, drawing on hazard and resilience science from the wider natural hazard research community.

Multiple Resilience Challenge research programmes have been involved in the project; the Rural Co-Creation Laboratory, as well as the Hazard, Infrastructure and Economics Toolboxes. In collaboration with QuakeCoRE, GNS Science and EQC, these teams have developed the resilience science outputs required for the project to be a success. They have used a scenario-based co-creation method, in which emergency managers, earthquake hazard and disaster resilience scientists and partner organisations work together to build a clearer picture of what a future earthquake event might look like across the South Island. The following outlines some of our work over the past two years.

The main output has been the development and socialisation of the SAFER framework, which has as its foundation a robust, scientifically credible Alpine Fault scenario. New science on the impacts and consequences of a future Alpine Fault event, including restoration timeframes and impacts on critical lifelines infrastructure were developed through strong relationships between West Coast Lifelines infrastructure organisations and researcher teams. In partnership with RiskScape, models of casualties, injuries, building damage, habitability and displaced populations were developed. The models have been highly commended by CDEM Group Managers, having added an important element of realism to the scenario, and allowed regional CDEM groups to tailor their response plans to the needs of their local area.

An initial assessment of the economic disruption impacts associated with an Alpine Fault event was undertaken using the 'Measuring the Economics of Resilient Infrastructure' (MERIT) tool – a novel analytical model that simultaneously quantifies the economic consequences of infrastructure failure across space and through time for multiple stakeholders. The MERIT modelling has revealed significant impacts to the New Zealand economy generated by an Alpine Fault earthquake. Although MERIT covers all economic sectors, the project focused on the regionally significant dairy manufacturing, coal mining and tourism sectors. This included modelling three dairy sector sub-scenarios constituting **high**, **medium** and **low** physical impacts, which when considered together give a broad indication of financial impact. As an example, one year after an Alpine Fault earthquake the loss in Gross Domestic Product (GDP) is estimated to be between $\text{NZ}_{2015}\$156$ and $586 million, depending on sub-scenario. Most of the impact would be felt in the West Coast region, making up 87% of the total GDP loss. Dairy product manufacturing is estimated to be the most affected industry, making up between 12% and 59% of the GDP loss depending on sub-scenario.

CDEM Stakeholder workshop for Project AF8.

Building on the relationships developed through the AF8 co-creation process, the 7-day AF8 hazard scenario has been extended out to 10 years post-quake, known as the 'AF8+ scenario'. Infrastructure outages and their subsequent recovery were developed over this extended timeframe, and are being used to guide recovery planning and for the development of long-term resilience collaborations between lifeline organisations and communities on the West Coast.

The AF8+ scenario is also being used to assess new methodologies to quantify the resilience of infrastructure networks across the South Island. The National Interdependent Infrastructure model, able to simulate the propagation of network disruption both within each network itself (direct) and across into other networks (indirect), was used with the AF8+ scenario to quantify the expected direct and indirect disruption throughout the recovery process. A new electricity resilience framework is being assessed using this scenario, including application of new methods to manage the power system and to rapidly restore functionality if the West Coast is cut off. The outcomes of these projects will help assess pre- and post-event investment decisions.

As can be seen throughout the work of these research programmes, the key to the success of this initiative has been collaboration with stakeholders. To date 64 workshops or science presentations have been run with a combined 4,350 attendees, which have included stakeholders from local government, MCDEM, District Health Boards, police, private corporate stakeholders and CDEM Groups from Southland to Nelson-Tasman and Wellington. These workshops have brought all the parties together for the first time to discuss this major hazard event, and have provided each group with the opportunity to highlight their capabilities and challenges. Open conversations help us all learn how we can collectively respond, by breaking down traditional silos and working across jurisdictions. The activities have catalysed a number of disaster resilience projects and initiatives within many of these organisations to enhance disaster planning and preparedness, from local community groups through to national agencies.

The success of Project AF8 has been driven by the strong collaboration across the natural hazard community, and engagement with key agencies and organisations with a role to play in the response. Next steps for Project AF8 include greater outreach and engagement with at-risk communities, improving the social media presence of the project, evaluating the effectiveness of the science and engagement approach, developing new/improved impact assessment models, and working to ensure the excellent profile and achievements of AF8 continue for years to come. Because people are talking about the Alpine Fault, and let's face it, it is all about the people.

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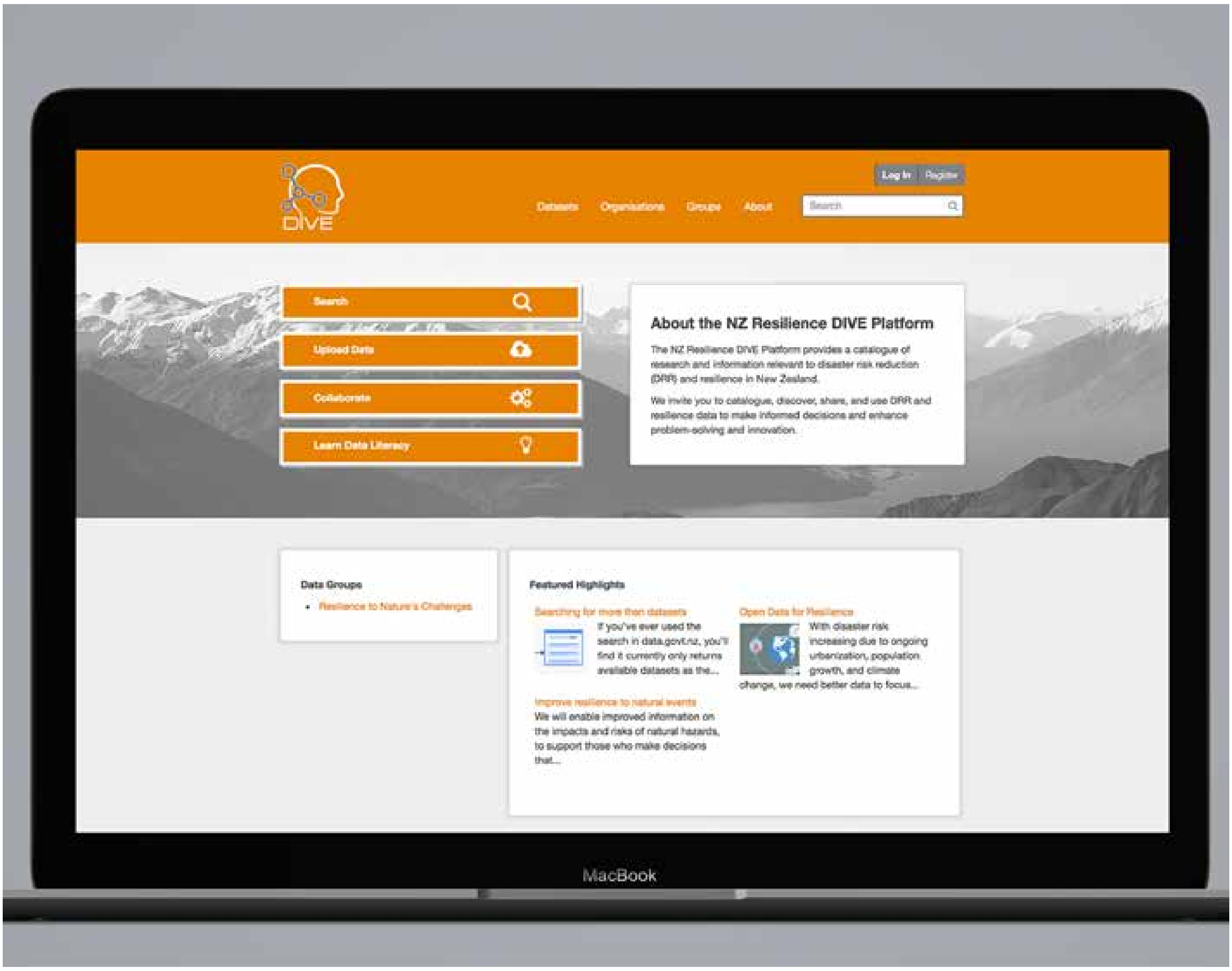
The Resilience Challenge Trajectories research team dicussing their toolbox's projects.

DIVE INTO A MORE RESILIENT NEW ZEALAND

By **JOANNE STEVENSON, ELORA KAY, AND JOHN VARGO**

The key to New Zealand's exciting resilience innovations might not be as far away as we think. In fact, it might already be sitting in the computers of researchers nationwide.

Across the country there are datasets from extensive, ongoing research on disaster risk reduction and resilience, but no integrated way to share and search that information. This seemed like a missed opportunity, so in 2016, a collaborative team of researchers funded by QuakeCoRE - New Zealand Centre for Earthquake Resilience and Resilience to Nature's Challenges ran a series of workshops. They wanted to find out the critical data needs for researchers and research stakeholders in the disaster risk reduction (DRR) and resilience space so that they could formulate a plan.



DIVE Platform datasets webpage.

Several key needs were identified. Researchers and stakeholders needed a system where they could find out about ongoing research before publication, and through which data could be easily searched for and shared across organizations. They also needed standards and guidance for transdisciplinary data management that facilitate data integration, analysis, and visualisation, and in addition, better access to public, proprietary, and sensitive data sources, and the ability to track data reuse.

In light of these findings, the team developed the Data Integration and Visualisation En Masse (DIVE) Platform. The NZ Resilience DIVE Platform website gives users the ability to catalogue, discover, share, and use datasets and other information relevant to DRR and resilience in New Zealand. DIVE is, first and foremost, a metadata catalogue, a place where people can let others know about the data, publications, and ongoing research relevant to DRR and resilience. DIVE also has the capacity to host unique datasets, and the team is currently working with researchers who have datasets that they would like a wider audience to access or reuse. The platform is also a place where those interested in DRR and resilience in New Zealand can connect and collaborate, forming virtual organisations for sharing information. Finally, DIVE provides access to data literacy tools for those wanting to know more about metadata and spatial data, and why these things are important for a more resilient New Zealand.

DIVE has been created using a software platform (CKAN) that can be transferred to another host (such as data.govt.nz) should the platform be decommissioned. This ensures the longevity of users' uploaded information.

The NZ Resilience DIVE Platform is created and maintained by Resilient Organisations and, ultimately, by New Zealand's research community. As a sharing platform, this collaborative site provides a tool for transformational research, allowing for innovative new discoveries through the recycling of data. It is also hoped that DIVE can act as a catalogue or repository for information produced in disaster response and recovery contexts and can aid decision making in the wake of natural disasters. DIVE can be accessed from resiliencedata.org.nz.

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TSUNAMI PREPAREDNESS IN THE CHATHAM ISLANDS

By **KRISTIE-LEE THOMAS**

Kristie-Lee Thomas speaking to students at Te One School.

August 15th, 2018 marked 150 years since the Chatham Islands were hit by three large tsunami waves, generated by a magnitude 8.5-9.0 earthquake off Arica (then in Peru, now in northern Chile). Waves of up to 6 metres inundated the islands, flooding over 6km inland and destroying buildings, bridges and homes.

A group of GNS Science researchers visited the Chathams to commemorate the event with the community, alongside Chatham Islands Council Emergency Management Office. Included in the group was researcher and Chatham Islands local Kristie-Lee Thomas, who recently completed her master's thesis with the University of Canterbury investigating tsunami risk to the Chatham Islands.

While there, Kristie-Lee shared findings from her thesis, which investigated both documented and Māori oral history accounts of past tsunami on the Chathams, including the 1868 event. As part of this research, which was supported by Resilience to Nature's Challenges, RiskScape, EQC, and the Ngāi Tahu Research Centre, Kristie-Lee studied archives and literature on the event, and also spoke with kaumatua (Māori elders) on the Chatham Islands who shared their knowledge about the tsunami.

As well as uncovering previously undocumented insights into the 1868 tsunami, Kristie-Lee's research helped to guide the locations of new tsunami evacuation zones on the Chatham Islands. The zones were determined using scientific modelling alongside Kristie-Lee's findings around past tsunami inundations, which were drawn from oral and documented accounts.

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Gathering at Waitangi West, acknowledging the fatality that occurred at this beach and also those who lost their lives nearby at Tupuangi where the village was destroyed and three families are thought to have been washed away.

Remnant of a European house at Tupuangi destroyed by the 1868 tsunami.

MĀTAURANGA MĀORI RESEARCH

PROVIDING NEW INSIGHTS INTO NATURAL HAZARDS AROUND NEW ZEALAND / AOTEAROA

By **JONATHAN PROCTER**

The Mātauranga Māori cross-cutting laboratory within the Resilience Challenge is supporting experienced and new and emerging Māori researchers to explore mātauranga Māori (Māori knowledge), from oral traditions, observations and historical accounts of natural hazards. This source of information and data contributes to our understanding of natural hazard events and also provides lessons on how to respond and recover, as well as explore more meaningful ways to communicate resilient solutions to Māori and New Zealand/Aotearoa.

The research is producing new hazard and environmental management tools and iwi development strategies that are based on long-lived traditional planning techniques that have been successful in the face of New Zealand/Aotearoa's natural challenges for over 500 years of human occupation. Two recent publications from the programme outline the contributions that investigating traditional practices can make to improving our knowledge of hazardous events and developing resilience (Gabrielsen *et al* 2017; King *et al* 2018).

The first paper by Hollei Gabrielsen explores the knowledge of volcanic events recorded by Ngāti Rangi and their past reactions and responses to volcanic phenomena. Ngāti Rangi and other tribes affiliated to the volcanoes of the central North Island are intimately connected to, and familiar with, the moods, signs, and language of the volcanoes and have valuable knowledge to contribute to warning system development and decision-making during and after volcanic events. Key learnings from this research are that Māori observed and noted various volcanic events and recorded their experience in waitata or songs that not only describe the physical phenomena occurring, but also provided practical advice on how to respond in the future. The following is from Gabrielsen's article:

O rongo Ruapehu. Turaki auahi. Puahiri Whakarunga. Ki whai tua ee

If you ever hear Ruapehu Erupting with ash. You can be comforted knowing. The prevailing wind takes it elsewhere

The northern coast of D'Urville Island where ongoing work alongside Ngāti Koata and Ngāti Kuia will take place over the months ahead. Photo: Emily Lane, NIWA.

Tukutahi te puehu turaki whakatua
Ka whakahoki mai hei tāpora mō
te nohoanga ia koutou mā eei.

Behold! An eruption of ash. Do not fear, this ash will cloak and replenish the land and help us live as one

A uniquely New Zealand lesson to be learnt from this research is that Ngāti Rangi regard Ruapehu as their ancestor, Koro or Matua te Mana, and personalise all volcanic activity as part of his moods and behaviour, which people living there should respect and to which they should pay attention.

The 2018 article of Darren Ngaru King provides an important account of tsunami activity in New Zealand and how people chose to respond to this, as well as insights into how to transfer knowledge associated with these natural hazards. Working alongside key informants from Ngāti Koata and Ngāti Kuia to explore traditional whakapapa, sites of significance, and histories and achievements of past ancestors, they confirmed experience with past tsunami - possibly multiple events - on and surrounding Rangitoto (D'Urville Island). The multiple layers of information gathered show a rich system of knowledge recording past catastrophic natural hazards and the corresponding response actions. This work not only contributes to the production of 'new' narratives about tsunami disturbance, recurrence and risk around the New Zealand coast, but also shows that skills in trans-cultural research enquiry will be required to advance our geosciences knowledge.

Mātauranga Māori is also being investigated in other areas of New Zealand (e.g. University of Canterbury and the Rekohu/Chatham Islands; Te Whare Wananga o te Awanuiarangia and the Te Moana-a-Toi/Bay of Plenty), unearthing many new accounts of natural hazards that will contribute to our understanding of the frequency and magnitude of such events in the past of New Zealand / Aotearoa.

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ADVANCES IN PREPAREDNESS FOR THE NEXT VOLCANIC EVENT

By **JONATHAN PROCTER, MARK BEBBINGTON AND STUART MEAD**

Over past decades, our understanding of individual volcanic eruptions, and our ability to simulate them, has progressed considerably. However, there is still more to do to address one of the key risk dimensions of volcanic eruptions: that is, to better understand their dynamic evolution during the course of an eruption sequence, and how it may lead to multiple, and strongly interdependent, hazards and impacts.

In the NHRP programme 'Quantifying exposure to specific and multiple volcanic hazards,' researchers from Massey Canterbury, Auckland, and Victoria universities and GNS Science are involved in two groundbreaking initiatives that are making significant advances in probabilistic modelling and computational simulation that will enable us to increase our preparedness for the next volcanic event.

Multi-hazard assessments raise operational and methodological issues that are often more complex than single hazard assessments. Multi-hazard assessments require a shift from hazard-centred to location-centred assessments and significantly increase the size and computational burden of the simulations. In this project, Stuart Mead is using a relatively new statistical technique to interpolate between simulation results and provide an estimate of the volcanic hazard intensity for all volcanic hazards, and all possible initial conditions, such as size and location. Previous simulations have simplified the relationship between volcanic processes and hazards, and are unsuitable for our project. We have developed an improved approach that broadly defines the form of the relationship between simulation inputs and hazard. These relationships are combined and fitted to simulation results to estimate hazard intensity (e.g., such as flow height for pyroclastic currents) at any input configuration and the uncertainty associated with this estimate, which is crucial. This innovative approach reduces the number of simulations needed to provide a hazard estimate and makes the problem of determining multi-hazard intensity computationally feasible.

We have developed a working model by simulating pyroclastic density currents originating from the summit of Mt Taranaki, as shown in Figure 1. Work is ongoing to adapt this methodology to all hazards.

Also in this project, Mark Bebbington is exploring the possibilities of forecasting the multiple phases within an eruption and applying this to past eruptions at Mt Tongariro (Te Maari, 2012) and Mt Pinatubo (1991). Forecasting eruption onsets, in both the short- and long-term, has received much attention. However, unlike an earthquake, an eruption is not easily reduced to an instant in time. Any usable definition of an eruption has to allow for activity over timescales ranging from minutes to decades, allowing for multiple eruptive phases. These phases can be defined by having different styles of activity and/or quiescent periods between them. Statistical advances have allowed us to calculate likelihoods for the next step of the eruption, conditional on, for example, the duration of the current phase, and the duration of the quiescence preceding it. This has been applied to the Te Maari eruption and Figure 2 shows the comparison between the model and expert opinion of the eruption's progression.

These research directions, new simulation tools and statistical models highlight the progress that is being made towards our ability to forecast future volcanic events and their impacts.

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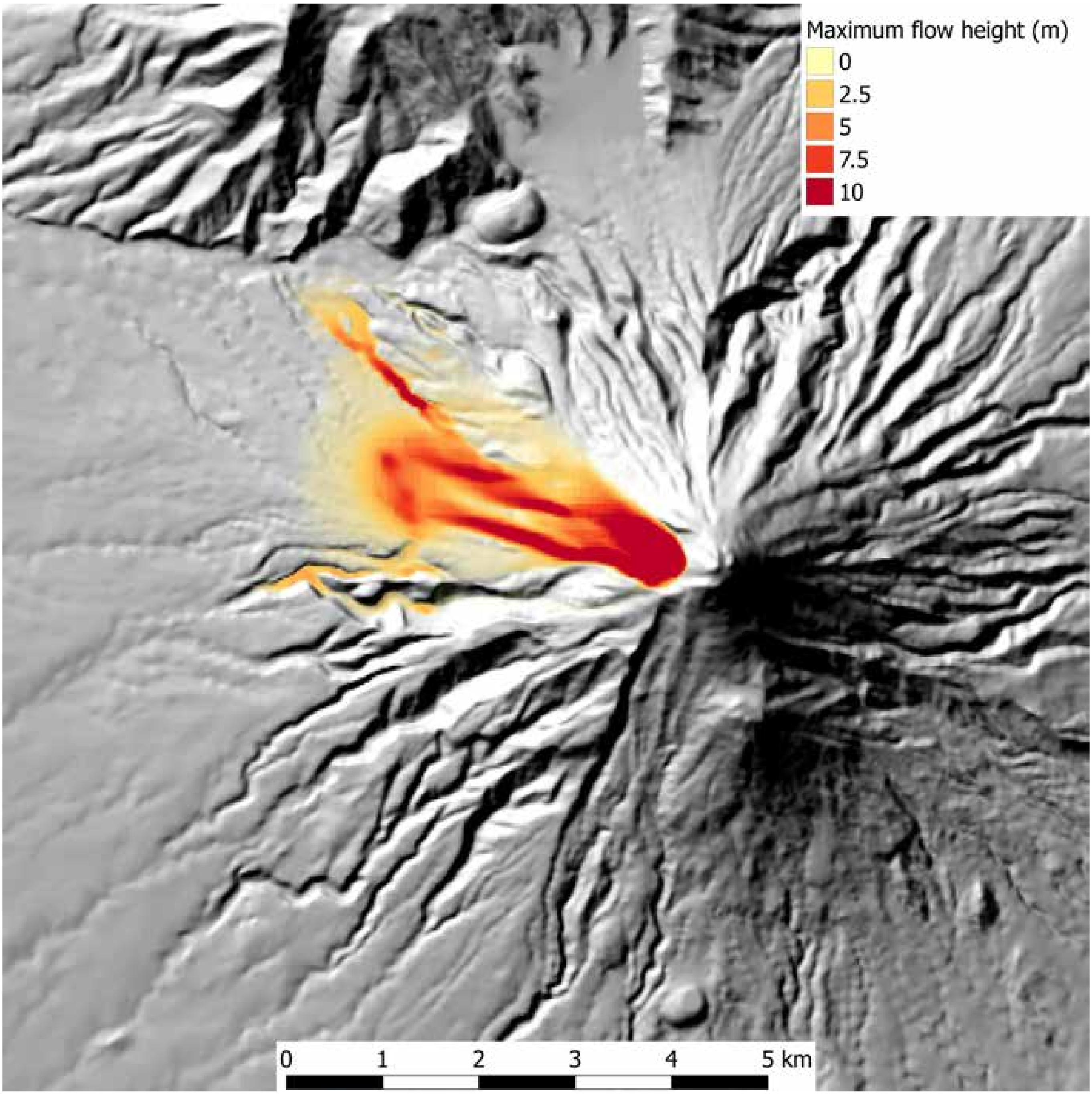
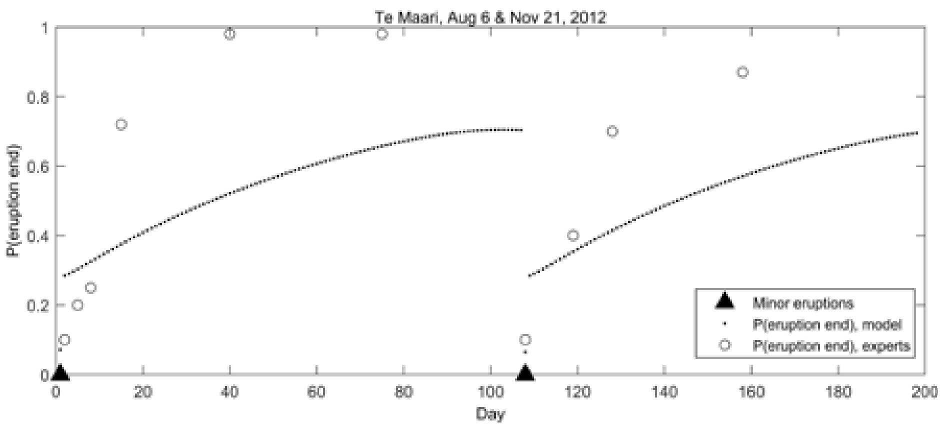


Fig 1. The potential hazard associated with a pyroclastic flow from Mt Taranaki using new computer simulation tools. The coloured areas show all possible inundation areas associated with pyroclastic flows. Red shading highlights the areas more likely to be inundated by pyroclastic flows.

Fig 2. A comparison between the statistical intra-eruption model and expert opinion of the probability that the 2012 Te Maari eruption has ended. The use of expert opinion contributes to the development of probabilistic models that tell us more about the potential of volcanic activity occurring.



CAN WE EVACUATE AUCKLAND BEFORE A VOLCANO ERUPTS?

By **SEOSAMH COSTELLO**

Resilience Challenge researchers have been investigating whether it would be possible to evacuate parts of New Zealand's largest city if an eruption occurred in its volcanic field.

There are at least 50 discrete volcanoes within a 20km radius of Auckland City, and the region has had repeated and varied volcanic eruptions in the past, with the last one (Rangitoto) occurring 600 years ago. While Auckland's volcanoes are relatively small, an eruption would cause serious problems due to high population densities. This is coupled with Auckland's geographic location being poorly suited for evacuation, with the only terrestrial routes out of the area being through two isthmuses (narrow sections of land that connect larger landmasses), creating a large potential for traffic congestion.

There has never been a mass evacuation of Auckland City, and there is limited data to suggest what might happen should residents need to evacuate. Plus, evacuation behaviour would vary tremendously depending on factors like the location, style, sequence and advance warning of the eruption.

Researchers in the Resilience to Nature's Challenges Infrastructure team are working to address some of this uncertainty through two research projects. The first is investigating how drivers behave in an emergency situation in Auckland. Currently we only know how drivers behave during regular daily activities, but how they behave under pressure could be quite different.

The second project is building a simulation model of Auckland's transport network. The model will estimate the time needed to evacuate affected areas, the number of people unable to evacuate in time, and the location of traffic bottlenecks in case of evacuation.

Findings from both of these studies will enable transport planners and emergency management officials to better prepare for an eruption and maximise the number of people safely evacuated.

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Traffic congestion on Auckland's SH16.
Photo: Daniel Blake,University of Canterbury.

NZ VOLCANO TEAMS ASSIST OVERSEAS

By **NATALIA DELIGNE AND GRAHAM LEONARD**

During 2018, New Zealand researchers supported overseas colleagues in two ongoing volcanic eruptions in the Pacific - first in Ambae, Vanuatu; then in Kilauea, Hawai'i.

Graham Leonard (GNS Science) and Sandrine Cevuard (VMGD) arrive in West Ambae, Vanuatu to survey ash and acid rain impacts from the eruption in March 2018. The team also set up drinking water sampling sites for ongoing monitoring. Photo: GNS Science.

Carol Stewart (JCDR) and Sandrine Cevuard (VMGD) collect ash, soil and vegetation samples from West Ambae, Vanuatu to assess the impacts. Photo: GNS Science.

New Zealand is known for its world-leading research programme concerning volcanic impacts, particularly in the areas of infrastructure, agriculture, and health; expertise that has made us a valued partner during eruption responses.

Volcanologists from GNS Science, the University of Canterbury, and Massey University provided in-country support to the Geohazards Division of the Vanuatu Meteorology and Geohazard Department (VMGD), involvement made possible with support from the New Zealand Aid Programme of the Ministry of Foreign Affairs and Trade. New Zealand has also provided remote support by undertaking laboratory work to assess ash and drinking water samples. The team has supported the development of key messages around dealing with volcanic gas, acid rain, and heavy ashfall, in addition to roof cleaning and the potential for roof collapse.

The current eruption at Kilauea, Hawai'i with concurrent activity at the Halema`uma`u summit crater and on the East Rift Zone, has received considerable media attention. Behind the scenes, New Zealand researchers have maintained and updated the USGS-hosted Volcanic Ash Impacts & Mitigation webpage, and answered questions from the public about how to best deal with volcanic ash.

Both eruptions have been difficult and testing for local communities. New Zealand's investment in researching volcanic impacts has directly assisted with the response to both of these events. These eruptions also provide valuable lessons that will help New Zealand when we in turn are faced with a local disruptive and damaging volcanic eruption.

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EARTHQUAKE IMPACTS ON WELLINGTON BUILDINGS

By **KEN ELWOOD**

Precast concrete units are commonly used as components of floors in New Zealand multi-storey buildings. Recent earthquake observations, including after the 2016 Mw7.8 Kaikōura earthquake, demonstrated significant issues that are being addressed by critical research.

Damage to Statistics House following the 2016 Kaikōura earthquake.
Photo: Statistics New Zealand.

The Canterbury and Kaikōura earthquakes have shed new light on precast concrete floors. The early use of these units in ductile concrete buildings has revealed support connections that were in some cases inadequate to accommodate earthquake-imposed deformations. This inadequate detailing potentially results in the precast unit being susceptible to collapse during ground shaking, as demonstrated by the floor collapse in Statistics House during the Kaikōura earthquake. Of particular concern is the fact that there was a general lack of specific design requirements provided for the support of precast concrete flooring systems during the 1980s, a time when construction in New Zealand was booming and the installation of such systems was extremely common. Hollowcore precast concrete floors were the predominant form of floor construction during this time period. Research at the University of Canterbury in the early 2000's identified the vulnerabilities of these floors and led to the development of support connection detailing (introduced in 2004) capable of accommodating large earthquake demands for hollowcore floors in new structures.

Damaged hollowcore floor after testing. Photo: The University of Auckland.

A Targeted Damage Assessment programme, initiated by Wellington City Council after the Kaikōura earthquake, identified a range of damage states to precast concrete floors in Wellington buildings. In several cases, the observed damage was inconsistent with the failure modes identified during previous research, bringing into question (1) the seismic assessment of buildings with precast floors; (2) the capacity of the damaged floor to sustain further earthquake shaking; and (3) the effectiveness of the existing retrofitting techniques.

To address the first concern, MBIE established a Working Group, chaired by Professor Ken Elwood, to develop guidelines for the seismic assessment of buildings with precast floors, based on past research and observations after the Kaikōura earthquake. At press time, these guidelines were under review by MBIE.

The second concern was addressed in the NHRP Kaikōura earthquake programme, with funding to examine the residual capacity of damaged hollowcore precast floors at the University of Auckland. This testing programme has identified that some of the damage observed in hollowcore floors after the Kaikōura earthquake must be attributed to the quality of the precast units in some 1980s buildings, as similar damage patterns could not be initiated in new units during testing. This test programme has also informed the development of the guidelines by the MBIE Working Group.

The third concern has led to a collaborative research proposal to validate retrofit techniques for precast floors, developed by the University of Auckland, University of Canterbury, and BRANZ. This planned programme will extend the NHRP work and engage closely with engineering consultants, contractors, and building owners to develop reliable and cost-effective retrofit solutions. It is anticipated that this research will begin in the second half of 2018.

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Damage to Statistics House following the 2016 Kaikōura earthquake.
Photo: Statistics New Zealand.

LIQUEFACTION OF RECLAIMED LAND AND IMPACTS ON PORT STRUCTURES

By **MISKO CUBRINOVSKI**

In the 2016 Mw 7.8 Kaikōura earthquake, the port of Wellington (CentrePort) experienced significant liquefaction that led to wharf and building damage, and temporary loss of operations. Liquefaction caused large settlement of the reclaimed land and lateral ground displacements towards the sea of up to 1.5 metres.

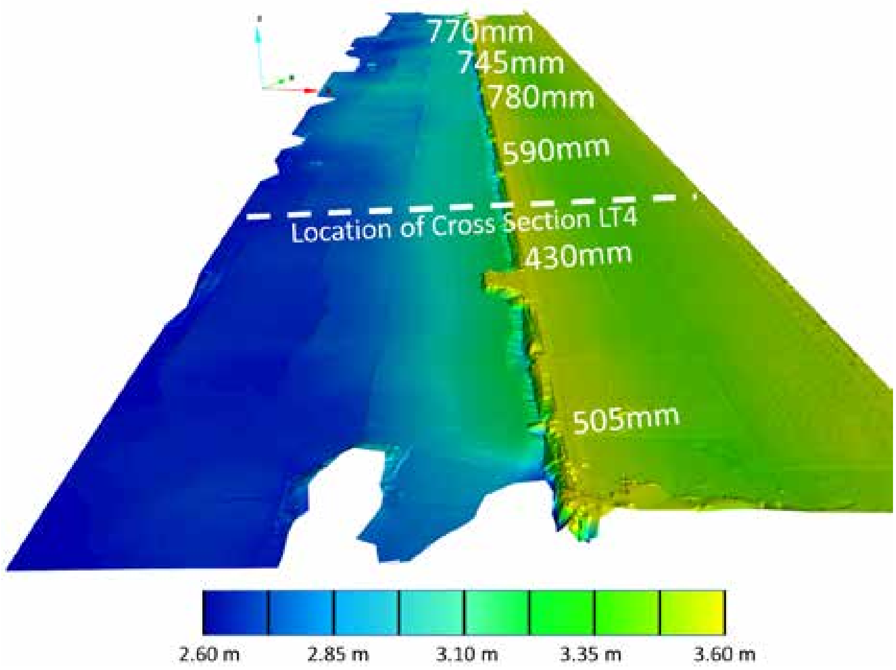
Reclaimed land is generally vulnerable to liquefaction. The degree of this vulnerability depends on a number of factors such as soil composition, soil density, soil age and the method of soil deposition (construction).

The reclamations at CentrePort were constructed using two different materials (dredged silts and sands from the original seabed and gravelly soils sourced from quarries), two different construction methods (hydraulic placement and end-tipping of soils), in two different time periods (approximately 1900-1930 and 1965-1975). Hence, the reclamations involve key aspects of soil composition, density, fabric and ageing effects on the liquefaction resistance in a unique way, specific to the conditions at CentrePort.

A detailed comprehensive site exploration program was carried out following the Kaikōura earthquake, to characterise the subsurface conditions at CentrePort. Cone Penetration Tests (CPT) were performed in the reclamations, and soil samples were collected for testing in the geotechnical laboratory to identify liquefaction characteristics of the fills.

Gravels have higher liquefaction resistance than sands, so much stronger earthquake shaking is required to liquefy gravels as compared to sands, and even when gravels liquefy, they deform less than sands. The gravelly fills at CentrePort contain 40-80% gravels, so it may be assumed that the reclamations exhibit a relatively high liquefaction resistance typical for gravels. One of our objectives was to

Liquefaction at CentrePort following the 2016 Kaikōura earthquake. Photos: University of Canterbury.



Digital elevation model of damaged wharf (green area) and adjacent reclamation (blue area) at CentrePort obtained from LiDAR surveying.

identify key soil fractions that control the behaviour of the fills during earthquakes. Our field investigations and laboratory studies indicated that even though the fills consisted predominantly of gravels, the soil matrix of the fills and their liquefaction resistance were controlled by the finer sand-silt fractions.

The liquefaction at CentrePort provided invaluable evidence on the impacts of soil liquefaction on the seismic performance of port structures. Liquefaction and lateral spreading radically change the foundation environment and earthquake-loading conditions for wharves and buildings, and for many structures these phenomena impose extreme seismic loading conditions. Understanding the characteristics of soil liquefaction is essential in the design of engineering structures. The research findings from these on-going studies will be implemented in guidelines for earthquake engineering practice in New Zealand, and will highlight critical issues in the seismic assessment of land and structures in the Wellington waterfront area, where a belt of approximately 200-500 metres from the present coastline is reclaimed land composed of similar soils and constructed with same procedures as the reclamations at CenterPort.

The reconnaissance work and follow-on field investigations at CentrePort included research contributions from QuakeCoRE and the National Science Foundation Geotechnical Extreme Events Reconnaissance programme.

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Damage from the 2004 Manawatu floods.
Photo: David Johnston, GNS Science.

HIGH IMPACT WEATHER INITIATIVE IN NEW ZEALAND

By **SALLY POTTER AND DAVID JOHNSTON**

The World Meteorological Organization's High Impact Weather research programme (HIWeather) aims to promote international collaborative research to improve global resilience to high impact weather.

The programme is three years into the 10-year plan, and is guided by five task teams covering:

1) predictability and processes;

2) multi-scale forecasting of weather-related hazards;

3) human impacts, vulnerability and risk;

4) communication; and

5) user-oriented evaluation.

Several cross-cutting activities span the teams, such as impact forecasting, social media, and investigating the value chain. The programme focusses on the hazards of urban flood, wildfire, localised extreme wind, disruptive winter weather, urban heat waves, and air pollution. New Zealand plays a role with David Johnston (Director, Joint Centre for Disaster Research) as the co-chair of the programme, and Sally Potter (GNS Science) as co-lead of the Communication Task Team. They are joined by other key researchers from the JCDR working across the HiWeather programme.

Research on weather and communication in New Zealand has contributed towards the goals of HIWeather. For example, collaborative research by GNS Science, MetService, Massey University, Wellington Region Emergency Management Office (WREMO) and East Carolina University (USA) is investigating the influence of impact-based severe weather warnings on risk perceptions and intended protective actions with New Zealand participants. Using a hypothetical strong wind event, the team found that while impact-based warnings can change risk perceptions, this does not necessarily influence intended protective actions. Future research will look at the role of including specific protective action guidance in weather warning messages, in comparison to impact information. Other areas of intended research may include post-event case study analysis, understanding vulnerabilities and impacts from weather events, and methods of evaluation.

They are also working to expand the HIWeather New Zealand network through the Meteorological Society of New Zealand (MetSocNZ). David Johnston and Sally Potter led the inaugural HIWeather NZ workshop at the November 2017 MetSocNZ conference in Dunedin. Numerous ideas were gathered on current activities taking place, as well as ideas for the way forward. Johnston and Potter hope to continue this momentum at future events, and welcome anyone interested in weather research and applications to contact them.

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Damage to a house at Ruby Bay caused by ex TC Fehi. Inundation depth is surveyed at each property, along with detailed damage and loss estimates. Photo: Ben Popovich, NIWA.

EX-TROPICAL CYCLONES IMPACTING NEW ZEALAND

By **RICHARD TURNER, RYAN PAULIK, AND BEN POPOVICH**

The passage of ex-tropical cyclones Fehi and Gita, in a backdrop of the hottest summer on record and a marine heatwave, had widespread impact and were a notable start to 2018.

Through March 2018, weather events caused at least $123 million in insured losses ($57 million due to Fehi and Gita), while in 2017 insured losses due to weather events were $224 million with $109 million due to ex tropical cyclones Debbie and Cook. Ironically, Debbie was the least intense but caused the most insured losses ($91 million) due to the breach of the stopbank resulting in the Edgecumbe floods.

A look back at historical records (Table 1) confirms that 2018 has been unusual (so far) for ex tropical cyclone activity and impacts in several respects. First, in terms of the number of events: 3 ex TC events compared to the long-term average of less than 1 per year (and 0.7 ex TC events for the entire period of 1960 to 2018); Second, the number of ex TC events crossing the South Island, which was 2 in the past year compared to the

Debris deposits at Ruby Bay as a result of ex-TC Fehi. The extent of debris helps researchers determine the run-up during an inundation event. Photo: Ben Popovich, NIWA.

long-term average of 1 every 5 years; Third, the intensity of the events, with Fehi ranked 3rd equal and Gita 6th in terms of how low the central pressures were; Last, the earlier occurrence in the calendar year (February & March), compared to previous events. The recent decade has also seen the highest number of ex-tropical cyclones impact New Zealand in any decade since the start of reliable records in the 1960's, though we could possibly extend this as far back as 1910 based on database records from the USA National Oceanic and Atmospheric Administration (NOAA; see Table, p.37). It is interesting to note the variability from decade to decade and how much more intense and frequent the recent events have been. This raises questions about what role the unusually high Tasman sea temperatures had in maintaining the intensity of Fehi and Gita, and whether this is a mechanism by which New Zealand might be more exposed to extreme weather under climate change.

Fehi and Gita were notable for their impact, causing widespread damage across New Zealand, resulting in state of emergency declarations for several regions. The West Coast, Nelson/Tasman, Kaikōura, Christchurch, Taranaki and Wellington were particularly impacted. Fehi also coincided with king tides associated with a blue-super moon, and this brought severe coastal inundation and coastal erosion along parts of the West Coast and in the Tasman district. Fehi's winds also caused damage to buildings in remote parts of the West Coast.

A NIWA team led by Ryan Paulik and Ben Popovich surveyed the damage from coastal inundation on 20 properties in the Tasman district. A key research question was to see whether the wave action and debris movement would result in different levels of damage when compared to similar inundation from river-flooding. Preliminary analysis suggests that only minimal differences are seen, which is useful as it allows vulnerability models developed for flood inundation to be applied to coastal inundation events without a loss of accuracy.

Each ex-tropical cyclone is unique in terms of its path, rainfall, storm-surge and wind patterns, so the magnitude and types of impact can vary hugely from storm to storm. Another current and exciting research project between OPUS, NIWA, and the University of Auckland is exploring this issue by using the results of very high resolution operational weather models to produce accurate 4-dimensional high-resolution simulations of each storm that has impacted New Zealand since 2014. The data provide a wealth of rigorously comparable information on storms that can be applied directly to impact and loss models. Such information has never been available before and is simply not available from coarse-scale reanalyses, historic weather event catalogues, or Tropical Cyclone track datasets. An example of the quantum leap in the level of information available from this modelling can be seen in Figure 1 (next page). It is hoped that future research will create this level of information for each ex-tropical cyclone that has impacted New Zealand since 1960. This will allow us to examine the impacts of sea surface temperatures on the role of the intensity of the 2018 storms and provide a detailed baseline for interpreting the impacts of future tropical cyclones.

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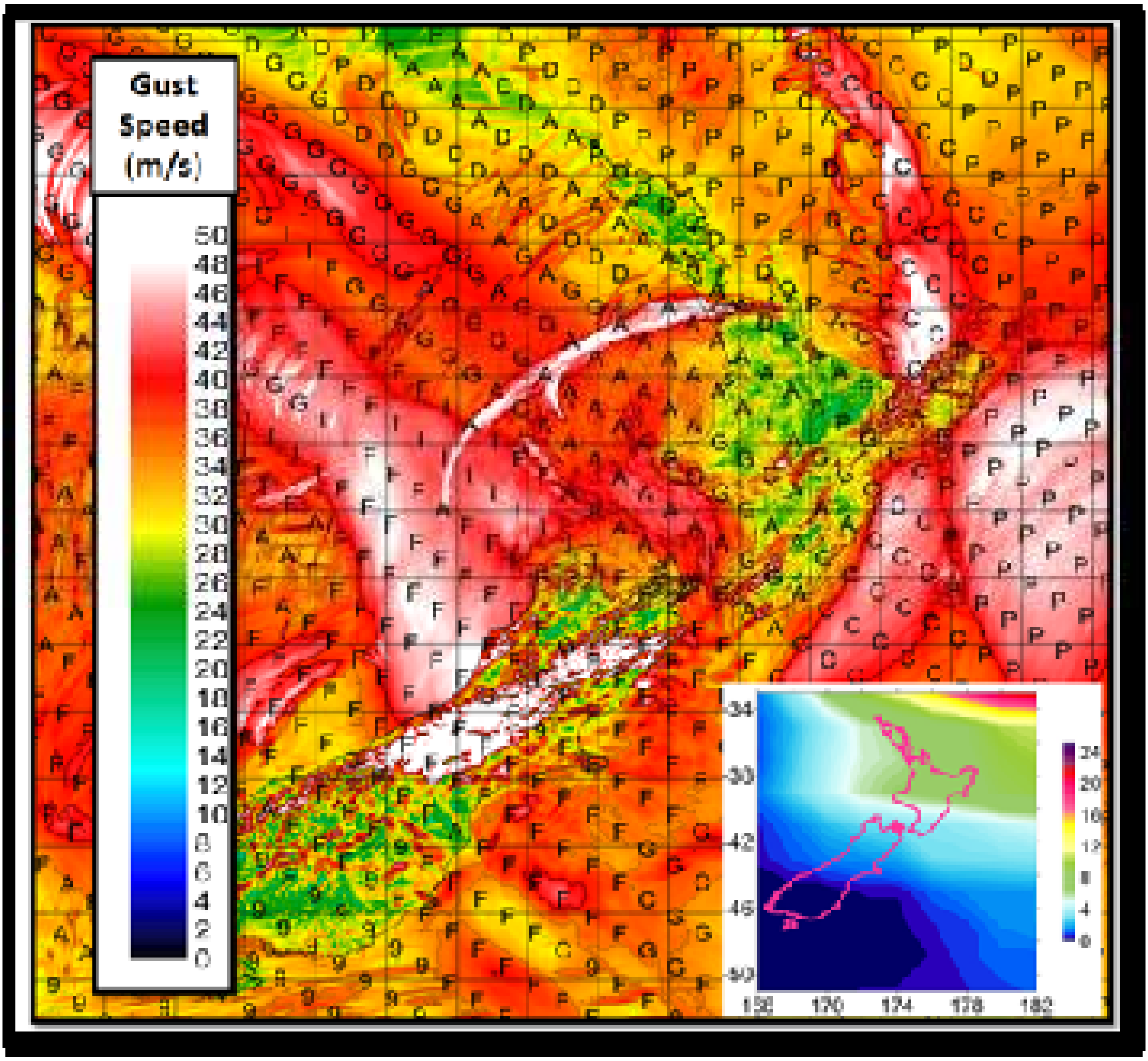

Fig 1. Maximum surface 3-sec gust over the four year period of 2014-18 associated with the passage of ex-TCs over and near New Zealand. Gust speeds are shown as a colour scale in the side bar. The letters specify which storm caused the largest gust in each location during this period: Ita (I), 99P, Pam (P), Victor(V), Cook (C), Donna (D), Fehi (F), Gita (G), Hola (H), and the 10 April 2018 Auckland wind storm (A). As an example, high winds from Pam were over a large area of sea, but on land only from East Cape to Gisborne. Inset: For the period 1960-2018, the average number of hours per year in which the centre of an ex-TC was within each latitude-longitude cell around New Zealand. Note that the upper North Island has been particularly affected by ex-TCs during this period.

Decade	Names of storms impacting or tracking close to NZ	Number / [number crossing South Island]	Lowest Pressure while centre within NZ latitudes (hPa). These are generally not available prior to 1970.
1910-1919	HD-1910, HD-1911, HD-1912, HD-1916, Zephon, Stentor, 3 un-named.	9 [0?]	
1920-1929	HD-1922 (2), 6 un-named	8 [0?]	
1930-1939	3 un-named (includes storm of century in 1936)	3 [0?]	**~970, 1936 storm**
1940-1949	HD-1948, 2 un-named	3 [0?]	
1950-1959	HD-1950 (2), HD-1951, HD-1952, HD-1956, Ida, 4 un-named	10 [2]	
1960-1969	HD-1961, HD-1963 (1+Henrietta), Barbari, **Gisele (Wahine),** Audrey, Dinah, 1 un-named	9 [4]	**(965 - Gisele)**
1970-1979	Nessie, Alison, HD-1976 (Watorea), HD-1977 (Norman), Hal, HD-1979 (Henry)	6 [2]	997, 980, 980, 997, 980, 980
1980-1989	NZ-1980(2, Simon, Sina), HD-1987(Patsy), **Bola,** Harry	4 [2]	985, 997, **975,** 990
1990-1999	Damian, Esau, **Fergus, Drena,** HD-1998 (Yali), Frank	5 [2]	992, 980, **979, 981,** 990
2000-2009	Ivy, NZ-2006 (Wati)	2 [0]	980, 995
2010- 2018(*)	Zelia, Wilma, Evan, June, **Lusi, Ita,** Ola, **Pam,** Victor, Debbie, **Cook,** Donna, **Fehi, Gita,** Hola	15 [3]	987, 978, 997, 987, **984, 971,** 997, **962,** 991, 994, **979,** 992, **971, 977,** 990

Listing of ex-tropical cyclones with NOAA's SPEArTC database that has tracked close to or over New Zealand since 1910. The list has also been augmented by comments from NIWA's historical weather event database and 2017/18 Southwest Pacific tropical advisories. Storms with notable impacts are in bold and numbers crossing the South Island are in square brackets. Numbers are less reliable prior to 1970, and central pressures generally not available prior to 1970. Note in the bottom row (2010-2018), 99P is not included.

THE WELLINGTON BASIN IN 3D:

MAPPING GROUND SHAKING PROPERTIES LINKED TO EARTHQUAKE DAMAGE

By **ANNA KAISER AND LIAM WOTHERSPOON**

The Wellington sedimentary basin had a critical influence on ground motions and damage patterns during the 2016 Mw 7.8 Kaikōura earthquake. A project led by GNS Science with colleagues at the University of Auckland and University of Texas at Austin uses a wealth of new data to improve the 3D model of the basin subsurface and update maps of key geotechnical properties. These outcomes can help us better understand and predict patterns of earthquake ground shaking, and be better prepared to mitigate future damage.

Motivation

As a consequence of the Kaikōura earthquake, Wellington experienced significant damage to numerous mid-rise structures in the central city. We know the pattern of damage from this particular earthquake can be linked to energetic seismic waves with periods of 1-2 seconds, similar to the natural periods of these types of buildings. Ground shaking at these periods was exacerbated both by the type of earthquake (a very large fault rupture propagating towards Wellington) and the presence of soils within the sedimentary basin which amplified shaking.

Resonance of seismic waves trapped within softer soil layers typically occurs at the 'site period', which varies depending on the layer thicknesses and wave-velocity through the soil profile directly beneath a particular location. However, additional complex 3D amplification effects can also occur in sedimentary basins, particularly at the basin edge where strong lateral material contrasts exist. Knowledge of the 3D basin subsurface and spatial variation of geotechnical properties such as site period is crucial to guide robust engineering design practices that take into account site-specific ground shaking characteristics.

The 3D Wellington basin model

We have updated the 3D Wellington basin geological and velocity model using newly available boreholes and geotechnical information. Interpretation of the borehole database allows us to more accurately delineate the shallow soil layers across the central city in 3D (Fig. 1) and better estimate the soil thicknesses. Where boreholes are drilled down to greywacke basement, they provide particularly useful constraints on the 3D subsurface structure and likely site period. However, where there is a paucity of deep boreholes (e.g. Thorndon and Centreport area), some gaps in our knowledge remain. We can use complementary geophysical data collected at the surface to better understand the soil response in these areas.

Complementary geophysical database

We have collected and collated over 450 geophysical site period measurements in the central city (Fig. 2). The majority of these measurements have been derived from analysis of seismometer recordings of ambient noise at closely spaced locations. In particular, new measurements collected in the deeper parts of the Wellington basin provide good constraints on the site period. We find that in the Te Aro basin to the south, the data illustrate a relatively simple pattern of site period variation within a steep-sided basin structure. However, variable and complex site amplification effects are observed within the Thorndon Basin to the north, which is bounded by the Wellington Fault. Our results suggest that the depth to greywacke basement may be deeper here than originally mapped and/or the presence of complex 3D basin-edge amplification effects may be complicating ground shaking patterns.

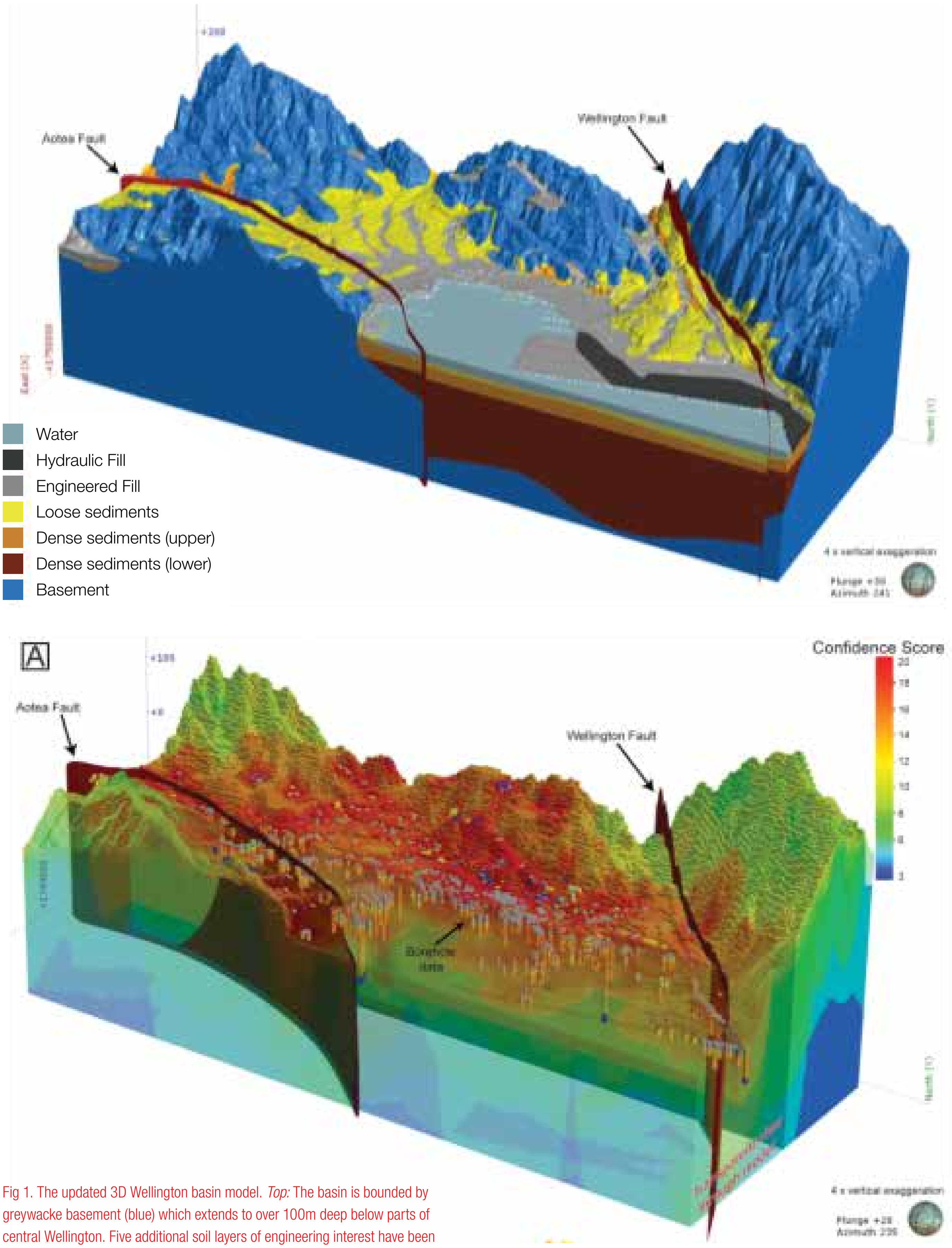

Fig 1. The updated 3D Wellington basin model. *Top:* The basin is bounded by greywacke basement (blue) which extends to over 100m deep below parts of central Wellington. Five additional soil layers of engineering interest have been mapped within the sedimentary basin. *Bottom:* Transparent view through the model showing the locations of borehole data and major faults. Colours indicate the degree of confidence in the model at that location.

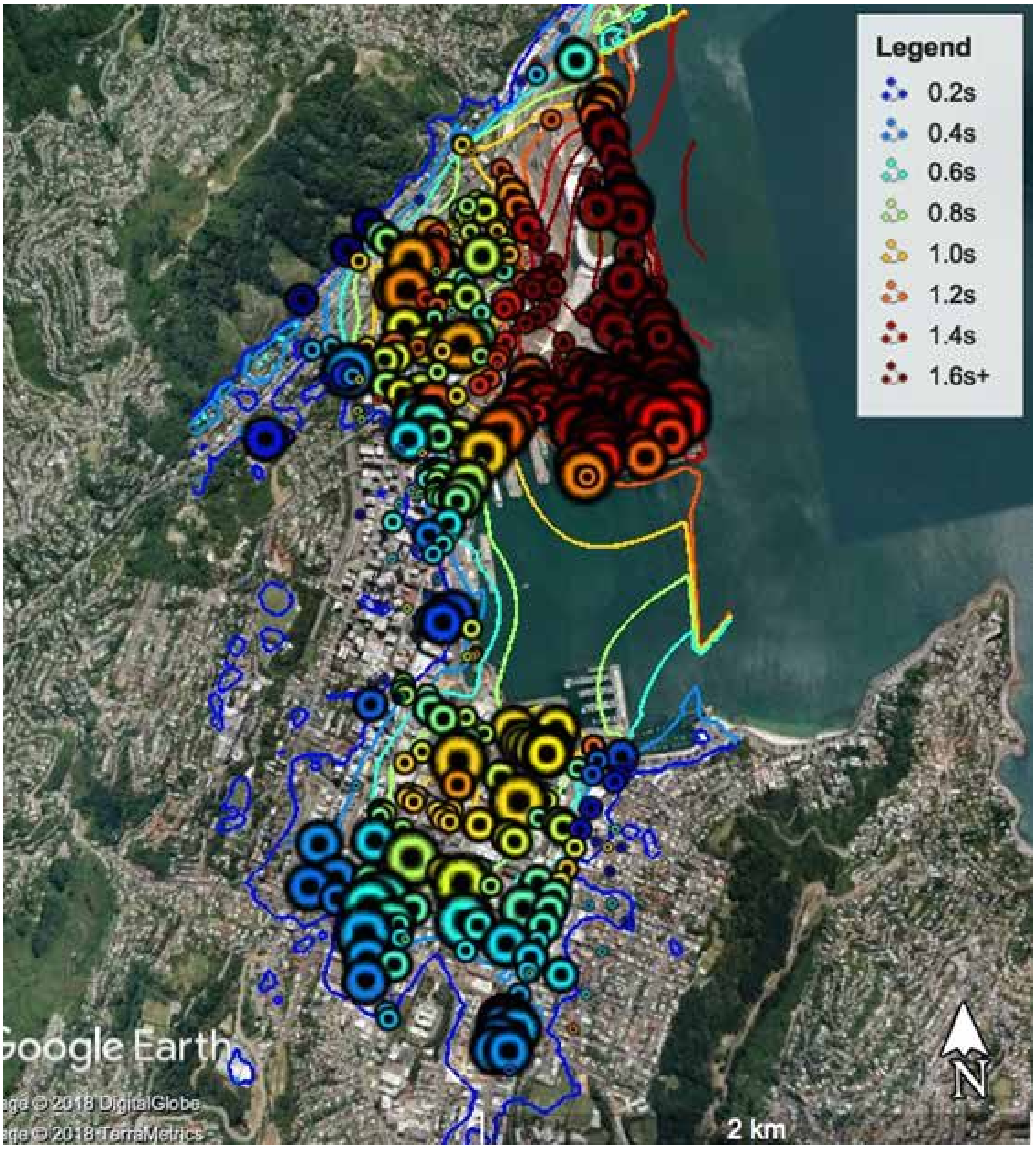

Fig 2. Database of over 450 geophysical site period measurements for central Wellington, including over 300 new measurements collected by the University of Auckland and University of Texas at Austin that have been reconciled with new and existing data collected by GNS Science. The site period corresponds to the colours indicated in the legend, whereas the confidence in each measurement is indicated by the size of the circle (the larger, the more robust).

Mapping geotechnical properties

By combining information from the 3D model and geophysical measurements, we can update maps of central Wellington site period and site subsoil classification. These maps are critical for the engineering community and local and central government, enabling them to guide and evaluate current design practices according to New Zealand's engineering code standards. They also allow improved assessment of damage patterns recently observed in Wellington. Furthermore, the updated 3D basin model is a critical component needed for simulation of shaking during both past and future earthquake scenarios. This ongoing research can be used to better understand and mitigate the impacts of complex site and basin amplification effects in Wellington.

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LIVING AT THE EDGE

By **EMMA RYAN**

How resilient are New Zealand seaside communities to coastal hazards like erosion and inundation, and to exacerbation of these hazards due to climate change and sea-level rise? Researchers from Resilience to Nature's Challenges have been exploring how to enhance the resilience of coastal communities in New Zealand through the 'Living at the Edge' research programme.

A beach gravel deposit in the front yard of an abandoned home in Haumoana, Hawke's Bay, where coastal erosion is a serious issue.

One of the projects within the 'Living at the Edge' programme has focused on adapting to coastal erosion and inundation from sea-level rise and storms. It uses approaches set out in the Ministry for the Environment Coastal Hazards and Climate Change Guidance, including using the Dynamic Adaptive Policy Pathways (DAPP) approach alongside Multi-Criteria Analysis and Real Options Analysis. These were used in a coastal context in Hawke's Bay, New Zealand, through the Clifton to Tangoio Coastal Hazards Strategy 2120.

The DAPP approach helps policy makers to develop adaptation strategies under deep uncertainty, such as that posed by climate change and sea-level rise beyond mid-century. The approach was introduced to the Hawke's Bay Strategy by Living at the Edge researchers acting as 'critical friends' of the process to develop a series of adaptation pathways for different sections of the Hawke's Bay coast. These pathways were then ranked using various criteria (including ability to reduce risk, environmental, social and cultural) to identify the adaptation pathways that enable early action, without closing off future ability to adapt and switch pathway over the long term. The DAPP approach allows short-term actions to start and enables long-term options to be identified and stress tested for action in the future, according to how the future unfolds. Action in the future is triggered using pre-defined signals and triggers (decision points) to determine when to switch adaptation pathway.

Another project has involved reviewing managed retreat as a coastal adaptation option for New Zealand communities. As climate change and sea-level rise encroach on and erode our coasts, physical protection options like sea walls and groynes become less viable. Managed retreat provides an alternative, pro-active adaptation option that allows the coast to naturally migrate, but there are few successful examples of the process in New Zealand or globally. 'Living at the Edge' researchers investigated approaches to managed retreat that have been undertaken both nationally and internationally, to find out what factors shape the outcomes of managed retreat initiatives. Their results, recently published in NZ Planning Quarterly, help to demystify

Broken and undermined seawall at Haumoana, Hawke's Bay after a large swell event in July 2017.

Tracking Radio-Frequency ID-tagged cobbles on Napier's foreshore as part of an ongoing sediment transport study.

Members of the Edge research team receive the inaugural Terry Healy Coastal Project Award.

the process, and aid policy-makers in developing detailed managed retreat strategies.

A third project undertaken through the 'Living at the Edge programme' was a survey of the Hawke's Bay public, to explore community values, perspectives and attitudes towards coastal hazards. Researchers found that Hawke's Bay residents value their coasts, and particularly appreciate being able to access them in their natural state. They also found that respondents were aware of the risks that coastal areas face, and were fairly unanimous in their opinion that something should be done to protect them as soon as possible. However, opinion on the most suitable approach and funding source were not so unanimous. These insights will prove invaluable throughout the next phase of research into coastal resilience actions for Hawke's Bay, as understanding perceptions and values are integral to notions of resilience and coastal planning.

Additional research has involved advancing knowledge about physical coastal processes through numerical modelling and field-based studies on gravel barrier beaches in southern Hawke's Bay. A numerical modelling study using XBeach-G software was undertaken to investigate the effects of storms and sea-level change on the physical response of the gravel barrier at Haumoana and this work is currently under review. Another study was conducted to explore sediment transport processes on gravel barrier beaches at Clifton and Awatoto. Beach cobbles were traced using a Radio-Frequency Identification system and Passive Integrated Transponder tags that allowed 1000 individual cobbles to be tracked on the beach across different time periods. These data allow the researchers to explore where and how the cobbles move on the beach and in response to differing wave and tide conditions.

Collectively, these research activities have:

1. Improved knowledge of coastal processes that impact coastal hazards in the region;
2. Fostered a wider understanding of coastal hazards and risk to develop decision-making tools and practical and resilient pathways;
3. Demonstrated best practice stakeholder engagement with communities vulnerable to natural coastal hazards.

Findings from 'Living at the Edge' research are currently being written up and will be made available in international scientific journals over the next year. The project has been successful in allowing researchers to become embedded in an existing local government decision-making process. This will yield interesting and informative insights that will not only inform best-practice coastal management in New Zealand, but be of relevance to resilience research and initiatives in general.

In November 2017, the Living at the Edge project was awarded the inaugural Terry Healy Coastal Project Award from the New Zealand Coastal Society. This award is intended to commend a coastal project in New Zealand for its overall commitment to excellence working within the coastal zone.

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NATURAL HAZARDS

A brief snapshot of the main events.

EARTHQUAKES

In 2017, GeoNet recorded 28,600 earthquakes in New Zealand, above the annual average, which is around 20,000. Aftershocks of the 2016 M7.8 Kaikōura earthquake continued to occur along the Kaikōura coastline, and near Cape Campbell. In 2017 there were 24 earthquakes recorded with magnitude greater than 5, the largest of which was a M5.7 earthquake southwest of Fiordland in the Puysegur Trench on 26 August, and a M5.6 earthquake 15 km west of Kaikōura on 22 October.

Between February and May, a swarm of more than 2,000 earthquakes occurred about 10 km west of Turangi in 3 separate pulses. Most of these swarm events were below M3, although the largest was M4.5. This swarm of earthquakes occurred mostly between 5 and 9 km depth, in an area known as the Taupō Volcanic rift zone. The TVZ is a rifting area, growing wider each year by 6-9 mm. These earthquakes were located on the western boundary and are likely to be related to the long-term 'tectonic' stretching of the Zone. There was no indication that the earthquakes were related to volcanic activity, being located well away from the active volcanoes. GeoNet continues to closely monitor the area.

TSUNAMI

Two notable tsunami events affected New Zealand in 2017. Fortunately, neither caused any damage.

On 8 September, a M8.2 earthquake occurred offshore of Chiapas, Mexico. This earthquake caused a tsunami with maximum reported run-up heights of about 2.7 metres on the coast of Mexico. In New Zealand, a marine threat tsunami warning was issued for the Chatham Islands, Banks Peninsula, Pegasus Bay, and the East Cape region. Geonet's gauges recorded tsunami amplitudes of 34 cm at Owenga in the Chatham Islands, and 23 cm in Gisborne.

An unusual tsunami from an apparently volcanic source occurred on 8 December, originating near Cheeseman and Curtis Islands which lie south of Raoul Island on the Kermadec Ridge. The tsunami generated coincided with an earthquake of M5.9. Signals of the tsunami were observed on seven tide gauges in New Zealand, the largest of these nearly 50 cm in amplitude on the Chatham Islands and 25cm on Great Barrier Island. The exact mechanism(s) leading to this tsunami are unknown, but an almost identical earthquake and tsunami occurred in the same location in 2009.

LANDSLIDES

Landslides have continued to impact New Zealand communities. The landslides we know of are those that are reported in the media or are mapped as part of our ongoing landslide research, many others may go undetected. Much of the landslide activity in the past year was triggered by rainfall, but there are also slopes made vulnerable by past seismic activity, human activity (engineered slopes), and a combination of these. In 2017, 2,398 landslides were categorised as small (involving less than 1,000 cubic metres of material), 83 were medium (1,000-10,000 cubic metres) and 5 were considered large (greater than 10,000 cubic metres).

Extreme weather from ex-TC Debbie caused several of the landslide dams formed by the Kaikōura earthquake to overtop, in addition to causing landslide debris flows that flooded SH1 north and south of Kaikōura.

VOLCANIC HAZARDS

Currently, two of New Zealand's cone volcanoes are showing signs of volcanic unrest, with Volcanic Alert Levels of 1. These are Whakaari (White Island) off the Bay of Plenty Coast, and Mt Ruapehu in the Tongariro National Park. All of the caldera volcanoes remain quiet, in addition to the Auckland Volcanic Field and Mt Taranaki.

Following eruptive activity in 2016, Whakaari became quieter in 2017. High temperature gases dominated the volcanic output, primarily from the 2012 Dome area. The active crater floor ponded some water but no crater lake was present. The Crater Lake (Te Wai A-Moe) at the summit of Mt Ruapehu started to heat in the later part of 2017 and the flux of volcanic gas through the lake also increased. The lake temperature peaked at 42.7 °C in early September. There was no eruptive activity

LOW TEMPERATURE

January was the only month during 2017 when New Zealand's nationwide temperature was cooler than average (0.7°C below average). The summer of 2016/17 was the coolest summer in five years since 2011/12.

On 12 and 13 July, a cold southerly outbreak led to many North Island and some eastern South Island locations observing near-record low maximum temperatures for winter. This included Cape Reinga, which only reached 10.8°C on 13 July, the 3rd-equal-lowest winter daily maximum temperature on record there.

The lowest air temperature for the year was -14.6°C, recorded at Lake Tekapo on 29 July.

HEAVY RAIN & FLOOD

A series of ex-tropical cyclones (TC) and storm events caused significant damage across parts of New Zealand and hampered Kaikōura recovery efforts along State Highway 1. During 7-12 March 2017, the 'Tasman Tempest' caused significant rainfall and flooding in the upper North Island. Floods and slips occurred in southeast Auckland and Coromandel, and Auckland's water supply was restricted due to siltation of reservoirs in the Hunua Ranges. On 4-5 April, ex-TC Debbie brought significant rainfall to the upper North Island and particularly to the Bay of Plenty where failure of a stopbank on the Rangitaiki River resulted in massive flooding in Edgecumbe, up to 1.5 metres high in places. About a week later (13-14 April), ex-TC Cook brought extensive rain and high winds to the upper and eastern North Island, with flooding in Christchurch.

On 21-22 July, heavy rain and high tides led to hundreds of homes evacuated and a state of emergency in Waitaki, Dunedin, Christchurch, Selwyn, Timaru, and eventually the entire Otago Region, as floodwaters inundated coastal eastern parts of the South Island. During this event, Oamaru had its wettest day on record since daily records started in 1950, with 161 mm.

COASTAL HAZARDS

Storm events in April and May 2017 produced significant wave heights and costly damage along the coast. On 12-13 April, ex-Tropical Cyclone Cook impacted the North Island, producing wind gusts of 165 km/h on Great Barrier Island, before moving south with heavy rain throughout the country. Waves recorded at Pukehina Beach in the Bay of Plenty reached a height of 8.2 metres, with a maximum individual wave height of 12.4 metres. Total costs of storm damage from ex-Tropical Cyclone Cook were estimated at $17.4 million (https://www.icnz.org.nz/natural-disasters/previous-events/)

On 21 May a storm occurred in Wellington with significant wave heights of 8.5 metres recorded off Baring Head. The largest individual wave height was 15.1 metres, with large southerly waves causing multiple cancellations of Cook Strait ferries. Further south, a wave buoy near Campbell Island (deployed by MetOcean Solutions and the New Zealand Navy) recorded a 19.4 metre wave on 20 May, which is the largest ever recorded to date in the Southern Hemisphere.

HIGH TEMPERATURE

2017 was New Zealand's fifth-warmest year on record, according to NIWA's Seven Station Temperature Series which began in 1909. Mean temperatures were above average for much of the North Island and parts of the South Island. Three locations - Te Puke, Wairoa and Lauder - recorded their warmest year on record and many locations recorded near-record high and low temperatures for the year.

The end of 2017 saw extended periods of high temperatures, culminating in the second-warmest December on record for the country. This was in part due to air temperatures being warmed by the Tasman Sea marine heatwave, which lasted from November 2017 to March 2018.

December 2017 saw new mean temperature records set at some of New Zealand's longest-running climate stations: Nelson, Levin and Ranfurly each epxerienced their warmest December since 1862, 1895, and 1897, respectively. Meanwhile, Cromwell experienced 23 consecutive days with a maximum temperature of at least 25°C, ending on 10 December. This was the longest stretch of hot days on record for this location.

The highest air temperature for the year was 35.5°C recorded at both Wairoa and Ashburton on 6 February.

SNOW, HAIL & ELECTRICAL STORMS

July snowfall made for dangerous driving conditions and resulted in road closures and flight cancellations.

On 1 July, SH8 between Twizel and Fairlie, and SH80 between Aoraki-Mt Cook and Ben Ohau, were closed due to snow. Snowfall also cut road access into Tekapo and Mt Cook, and contributed to two buses sliding off the road. From 5-12 July, snowfall followed by clear and cold conditions caused prevalent black ice on roads across the lower South Island. Numerous vehicle incidents were attributed to the black ice and roads were closed and flights cancelled or diverted. On 13 July, snow closed most of the South Island passes and State Highways in the central North Island. A dozen people were rescued from their cars on the Napier-Taupō Road, and a group of bus passengers had to spend the night at the Waiouru army barracks. Several thousand houses went without power overnight after heavy snowfalls downed lines and flooding created havoc. Damage was spread across a large swathe of the lower North Island including Wairarapa, Manawatu, Whanganui, Taranaki, Ohakune, Waiouru and Taihape.

On 6 July, Auckland flights were put on hold and some diverted as thunder, lightning and torrential rain passed through. More than 700 lightning strikes were recorded across the Auckland region with the Sky Tower taking four direct hits. On 5-6 September, 1,500 lightning strikes were recorded over New Zealand. Three homes were struck by lightning in Kohekohe, with one suffering extensive roof damage. In Mangakino, lightning hit the town's telephone exchange, cutting landline connections, and lightening set the Pureora Forest Park DOC office on fire completely destroying the structure. In Wellington's Newlands, Johnsonville and Paparangi suburbs, over 4,000 people lost power due to lightning strikes.

On 14 November a thunderstorm caused hail to blanket the ground in south Auckland, and blocked storm water pipes in Takanini, flooding a block of shops. Cloud-to-ground lightning was common from Waikato into southern Northland, including a 27-strike burst in 5 minutes. On 30 November, thunderstorms around Taranaki caused ping pong ball-sized hail in Urenui. The storms were caused by a warm, humid airmass along with converging winds in the lower atmosphere.

LOW RAIN & DROUGHT

2017 began on a dry note with Gisborne experiencing its driest January since records began in 1905, and Napier its 3rd-driest January since 1870.

Late 2017 saw significant dryness spread through much of the South Island and lower North Island. Christchurch had a 47-day dry spell (< 1 mm of rain per day) that ended in December, the longest dry spell in the city's 154-year record. Wellington also experienced a near-record 30-day dry spell ending in December. Due to the dry conditions, the Ministry for Primary Industries declared a medium scale adverse event for Taranaki, western parts of the Manawatu-Whanganui region, and in Wellington.

According to the New Zealand Drought Index,* 11 of New Zealand's 16 geographical regions were experiencing meteorological drought as of 31 December 2017.

*https://www.niwa.co.nz/climate/information-and-resources/drought-monitor.

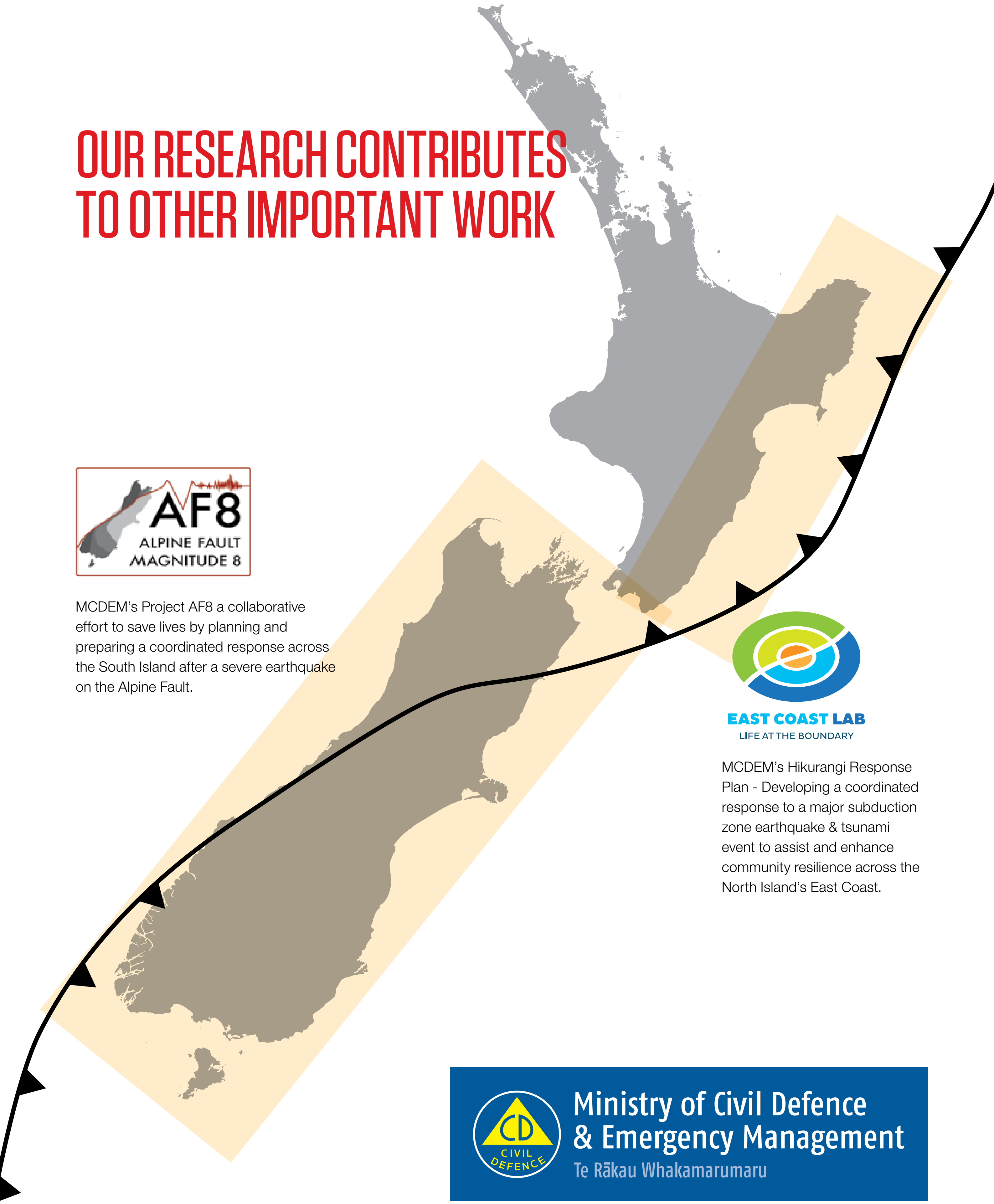
For more info, visit –

GeoNet: www.geonet.org.nz

NIWA's National Climate Summaries:

www.niwa.co.nz/climate/summaries

OUR RESEARCH CONTRIBUTES TO OTHER IMPORTANT WORK



AF8
ALPINE FAULT MAGNITUDE 8

MCDEM's Project AF8 a collaborative effort to save lives by planning and preparing a coordinated response across the South Island after a severe earthquake on the Alpine Fault.

EAST COAST LAB
LIFE AT THE BOUNDARY

MCDEM's Hikurangi Response Plan - Developing a coordinated response to a major subduction zone earthquake & tsunami event to assist and enhance community resilience across the North Island's East Coast.

CD CIVIL DEFENCE
Ministry of Civil Defence & Emergency Management
Te Rākau Whakamarumaru

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