Te Hiranga Rū | QuakeCoRE

Aotearoa New Zealand Centre for Earthquake Resilience

2023 Annual Report

Contents

Directors' Report 2023

Te Hiranga Rū QuakeCoRE formed in 2016 with a vision of transforming the earthquake resilience of communities throughout Aotearoa New Zealand, and after eight years of Tertiary Education Commission funding, we are seeing important progress toward this vision through our focus on research excellence, deep national and international collaborations, and human capability development.

In our seventh Annual Report we highlight several world-class research stories, collaborations with national and international partners, and education of the next-generation of researchers. Te Hiranga Rū QuakeCoRE researchers continue to excel in disciplinary research that is both scientifically excellent as well as impactful. Furthermore, as we continue to consolidate our research community, we are increasingly seeing impactful multidisciplinary research emerge that is solving traditional research questions in innovative ways. This Annual Report highlights several major examples of how the Te Hiranga Rū QuakeCoRE research community and its latent human capability are being harnessed to address major strategic research initiatives; the completion and dissemination of the National Seismic Hazard Model, involving over 30 peer-reviewed journal articles and the development and the on-going curation of the CEISMIC digital humanities database of human-stories associated with the Canterbury Earthquake Sequence. The Cyclone Gabrielle weather-related event profiled in this report also illustrates how earthquake resilience expertise and human capability can be harnessed to address the impact of other natural hazards. As well as examining the benefits of earthquake resilience for other natural hazards, this report also highlights the embodied carbon impacts of buildings designed for earthquake resilience, and how explicit consideration of this can lead to improved seismic performance and also lessen climate impacts associated with building demolition.

As a Tertiary Education Commission Centre of Research Excellence, Te Hiranga Rū QuakeCoRE has a strong emphasis on human capability and capacity development, and harnessing such development through the communities we interact with, and the places and fora that members of the Te Hiranga Rū QuakeCoRE community participate in in their professional and personal lives. This Annual Report highlights one initiative in the human capability pipeline – Early Career Researchers (ECRs), specifically, the establishment of an ECR network within Te Hiranga Rū QuakeCoRE, and two examples of outstanding early career researchers who have benefited from Te Hiranga Rū QuakeCoRE collaboration and engagement to produce high-impact research.

As we continue to progress our research programme and activities for the 2021-2028 funding period, we are excited to address transformative research questions in partnership with mana whenua, industry, national and international research partners. We will continue to develop the next generation of leadership capability toward our collective vision of earthquake resilience.

Brendon Bradley
Director

David Johnston
Deputy Director

Kelvin Tapuke
Pouwhakahaere

Caroline Orchiston
Associate Director

Liam Wotherspoon
Associate Director

Chair's Report 2023

Reflecting on the stories in this report, I feel that Te Hiranga Rū QuakeCoRE remains true to its engineering foundations through work on the National Seismic Hazard Model and other technical programmes. But I also sense a shift and growth in some of the connections we are now making with other emerging fields of research.

For example, all around Aotearoa New Zealand today infrastructure and building investments are subject to scrutiny through a climate change lens. I am encouraged that QuakeCoRE is connected to that field both through mitigation and adaptation research. As a nation we need to better understand the nexus between seismic resilience and our low carbon aspirations, it is pleasing to see this coming into focus through QuakeCoRE.

We also need to understand how more intense weather events and sea level rise will impact on geotechnical conditions and seismic risk for new and existing infrastructure. Again, QuakeCoRE is to the fore in leading thinking around the connection between seismic risk and climate adaptation.

There are real co-benefits from this kind of approach. We are on the cusp of a massive investment in housing, flood schemes, water pipes and transport infrastructure. If we can address seismic resilience now, we can increase community confidence and also benefit communities outside times of shock.

Further afield, according to the Rockefeller Foundation globally 53% of humanity currently lives in cities. This is expected to increase to 75% by the middle of the century. And in those cities, 70% of the infrastructure that will be in place by 2050 hasn't yet been built. This is both a massive challenge and a massive opportunity for QuakeCoRE researchers and our international colleagues.

QuakeCoRE has taken an approach that aims to build qualities such as flexibility, robustness, integration, resourcefulness, inclusivity and continuous learning into our research – and ultimately informing regulation, communities, infrastructure, and knowledge networks so that communities can survive and thrive following earthquakes – and also other shocks or stresses. This is the resilience dividend of QuakeCoRE.

Te Hiranga Rū QuakeCoRE remains in great shape and I am grateful for the oversight and advice of Board members Tā Mark Solomon, David Brunsdon CNZM, Ian Wright, Peter Gostomski, Wendy Saunders, Richard Clarke and Ellen Rathje. I especially would like to again thank Director Brendon Bradley and Operations Manager Ruth Hartshorn for their mahi. Kia ora.

He toka tū moana, ara he toa rongonui

Mike Mendonça, MBE
Board Chair

About Us

Te Hiranga Rū QuakeCoRE is transforming the earthquake resilience of communities and societies, through innovative world-class research, human capability development and deep national and international collaborations. As a Centre of Research Excellence funded by the New Zealand Tertiary Education Commission, QuakeCoRE is a national network of leading Aotearoa New Zealand earthquake resilience researchers. QuakeCoRE is hosted by the University of Canterbury Te Whare Wānanga o Waitaha and has eleven other formal partners.

We enhance earthquake resilience across the country and internationally, by working collaboratively on integrated, multi-disciplinary programmes of world-leading research. Our research supports the development of an earthquake-resilient Aotearoa New Zealand.

Our Vision

We are creating an earthquake-resilient Aotearoa New Zealand where thriving communities have the capacity to recover rapidly after major earthquakes through mitigation and pre-disaster preparation informed by research excellence.

Our Strategic Impact

1 **Improved Earthquake Resilience**
We will contribute to a step-change improvement in the earthquake resilience of the nation's infrastructure from research-informed national and local policies, implementation standards and disaster planning.

2 **Improved Economic and Commercial Outcomes**
We will support Aotearoa New Zealand's long-term economic benefit through significantly improved seismic performance of Aotearoa New Zealand infrastructure, rapid business recovery after future earthquakes and the growth of engineering resilience innovation and business in the Aotearoa New Zealand construction sector driving international competitiveness.

3 **Improved Societal Outcomes**
We will enable communities to recover rapidly after major earthquakes through mitigation and pre-disaster preparation, informed by research and public engagement.

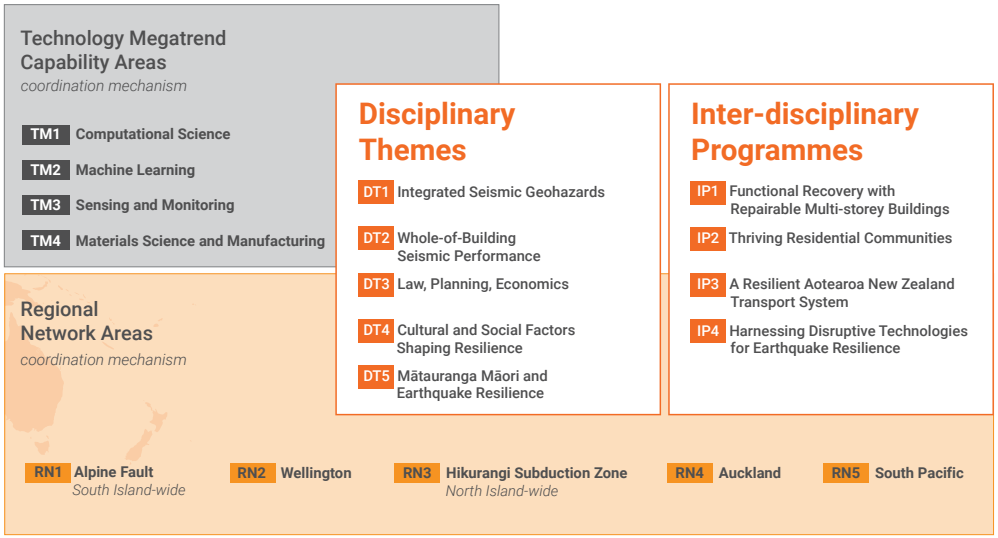
4 **Highly Skilled and Diverse Workforce**
Our graduates will be sought after for their knowledge of earthquake resilience and work-ready professional skills. They are taught in the very best national and international multi-disciplinary environment, combining research and industry elements. Through our graduates, we will seek a growth in under-represented groups (Māori and Pasifika) and gender equality in engineering disciplines.

5 **International Recognition**
We will be a focal point for international earthquake resilience, attracting the best talent and business alongside national and international research collaborations.

6 **Growing Mātauranga Māori**
We will contribute by building close engagement with Māori leaders who have responsibility for earthquake planning and resilience and developing opportunities for Māori capability building. The distinctive contribution of Māori indigenous knowledge of earthquake resilience will enhance social, economic and environmental outcomes for Aotearoa New Zealand.

Research Programme

Te Hiranga Rū QuakeCoRE continues to play a leading role in supporting and linking multi-institutional, investigator-led earthquake resilience research programmes that are internationally networked and recognised. Our research programmes are advancing the science and implementation pathways of earthquake resilience through system-level science with highly integrated collaborations coordinated across the physical, engineering and social sciences and across multiple research institutions. The research is principally organised into Disciplinary Themes, Inter-disciplinary Programmes and Coordination Mechanisms.



The **Disciplinary Themes** collectively span the disciplinary pipeline of earthquake resilience and focus on transformative research questions in which Aotearoa New Zealand researchers have shown global leadership.

The **Inter-disciplinary Programmes** bring together the diverse QuakeCoRE community through research questions that leverage Aotearoa New Zealand's unique environment and challenges toward the grand challenge of an earthquake-resilient Aotearoa New Zealand.

The **Coordination Mechanisms** (Technology Megatrend Capability Areas and Regional Network Areas) accelerate the development of human capability in emerging technologies for leading-edge research and regional networks, for both illustrating the application of research and working with partners and stakeholders to implement our research into tangible resilience advances.

Disciplinary Themes

DT1 **Seismic Demands and Consequent Geohazards**

Programme Area Leaders: Brendon Bradley, Rolando Orense & Tim Stahl

Advance understanding and modelling of individual earthquake-induced geohazards (ground motions, liquefaction, and slope instability), as well as unified data collection and modelling approaches to enable an integrated prediction in order to more efficiently mitigate future impacts and stimulate rapid advances in the profession.

DT2 **Whole-of-building Seismic Performance**

Programme Area Leaders: Rick Henry & Santiago Pujol

Develop fundamental understanding, and methods and models for the quantification of, whole-of-building seismic performance through direct consideration of structural and non-structural component interactions, as well as advances in seismic design and assessment considering life-cycle analysis.

DT3 **Law, Planning & Economics**

Programme Area Leaders: Ilan Noy, John Hopkins & Olga Filippova

Investigate economic impacts of earthquakes, and create the evidence base to inform regulation for effective planning, policy and mitigation to build resilience – including whole-of-economy earthquake impact modelling, assessment of specific resilience-building legal and planning tools and processes, and behavioural 'nudges' to incentivise resilience.

DT4 **Cultural and Social Factors Shaping Resilience**

Programme Area Leaders: David Johnston & Caroline Orchiston

Collaboratively understand, model and improve the critical cultural and social factors determining societal resilience to earthquakes in Aotearoa New Zealand, including human responses to earthquakes, temporal and spatial variation of risk, and building an earthquake-resilient society.

DT5 **Mātauranga Māori and Earthquake Resilience**

Programme Area Leaders: Anthony Hoete, Christine Kenney & Tūmanako Fa'aui

Community-led and co-designed participatory research to create and innovate mātauranga Māori (Māori knowledge) that will facilitate achievement of the earthquake resilience aspirations of tangata whenua. Knowledge translation of research findings will encourage increased understanding within Te Hiranga Rū QuakeCoRE, of iwi, hapū and whānau perspectives on earthquakes and disaster risk reduction.

Inter-disciplinary Programmes

IP1 **Functional Recovery with Repairable Multi-storey Buildings**

Programme Area Leaders: Geoff Rodgers & Alice Chang-Richards

Repair of earthquake damage is a critical component to the recovery after an earthquake disaster. After recent events, the time to return the commercial and industrial building stock to functionality has been hindered by the lack of understanding of residual capacity and repair. This programme will identify time-to-functionality targets and repairable building solutions, thus providing the underlying science to support the development of the world's first functional recovery-based seismic design standard.

IP2 **Thriving Residential Communities**

Programme Area Leaders: Tim Sullivan & Julia Becker

The Canterbury earthquakes illustrated the potential for large financial losses ($16B of $40B total) and multi-year disruption to Aotearoa New Zealand's residential sector, with significant implications on mental health and the disaster insurance market. This programme will tackle the problem of resilient housing – including effective engineering and technological solutions, land-use planning, improved insurance processes and frameworks, effective legislation, and communication and engagement strategies.

IP3 **A Resilient Aotearoa New Zealand Transport System**

Programme Area Leaders: Liam Wotherspoon & Charlotte Brown

A resilient transport and logistics system is critical to the ongoing and future viability of businesses and communities across the country, supporting the efficient movement of goods and people. This programme will integrate component and system-level modelling of networks and their users, consider interaction between different transport and logistics modes, and the social and economic impacts of disruption, to inform policy and investment decisions on the transport and logistics systems of the future.

IP4 **Harnessing Disruptive Technologies for Seismic Resilience**

Programme Area Leaders: Nirmal Nair & Garry McDonald

This programme will identify how transformational (i.e. order of magnitude) advancements in Aotearoa New Zealand's infrastructure resilience can be achieved through strategic adoption of disruptive technologies, via government and market-led initiatives. A central hypothesis is that rapid adoption of several disruptive technologies (e.g. distributed solar power) will result in a significantly greater resilience gain than the conventional wisdom of incremental investment to improve existing asset classes (e.g. centralized transmission networks).

Coordination Mechanisms

Technology Megatrend Capability Areas

Research technologies provide a platform upon which leading-edge research can be undertaken.
Our Capability Areas will accelerate the depth and extent of adoption by researchers in the Disciplinary Themes and Inter-disciplinary Programmes, and thus harness their transformative potential toward the earthquake resilience mission.

The four Technology Megatrend Capability Areas are:

- **TM1** Computational Science
- **TM2** Machine Learning
- **TM3** Sensing and Monitoring
- **TM4** Materials Science and Manufacturing

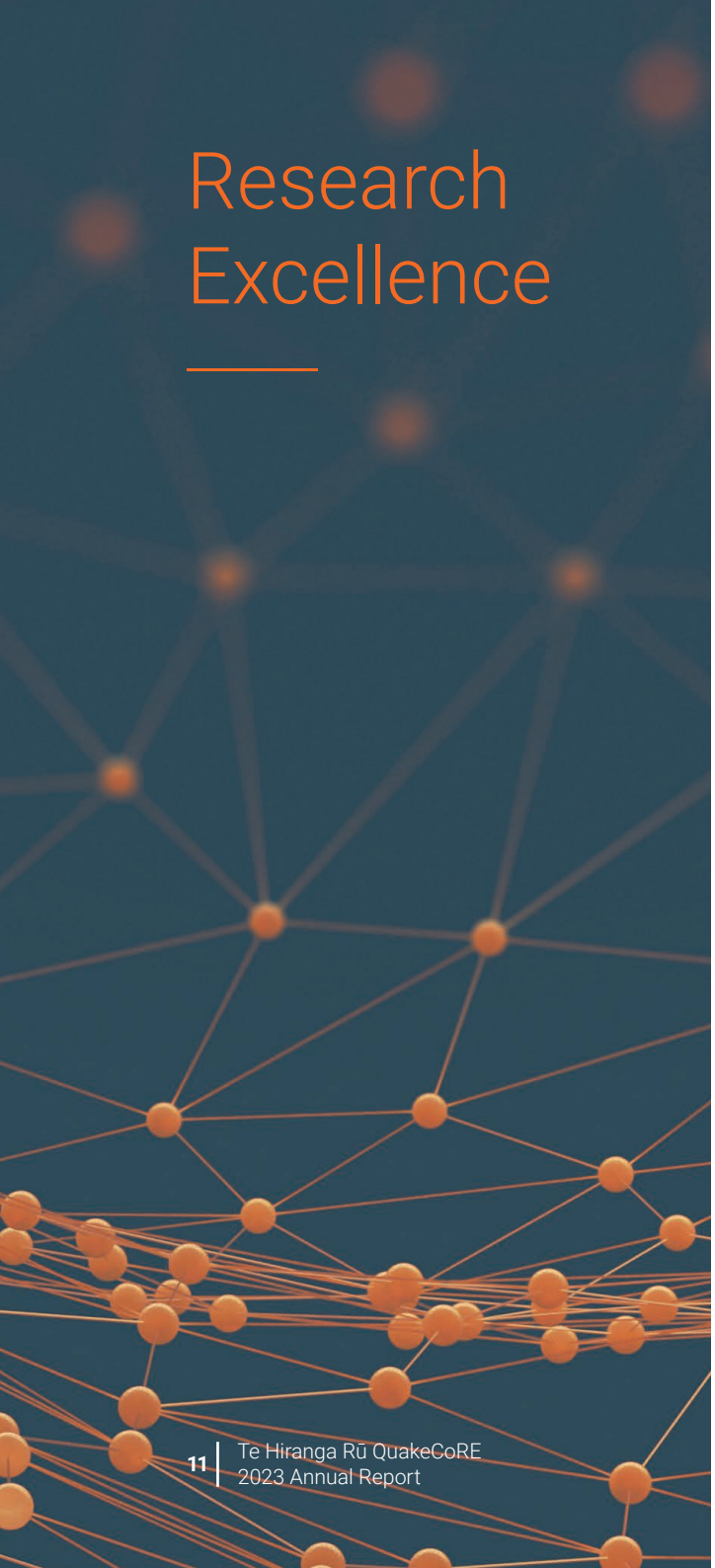
Regional Network Areas

The Regional Network Areas act as a focal point to provide contextual relevance and rapid embedding of research solutions. They provide a pathway for the application of our research and the collaboration with partners and stakeholders to translate research outcomes into tangible advances in earthquake resilience.

The five Regional Network Areas are:

- **RN1** Alpine Fault (South Island-wide)
- **RN2** Wellington
- **RN3** Hikurangi Subduction Zone (North Island-wide)
- **RN4** Auckland
- **RN5** South Pacific

Research Excellence



The Carbon Footprint of Seismic Resilience

Structural engineers have a powerful role to play in helping to stall climate change. Globally, an estimated 40% of carbon dioxide emissions come from the built environment. This presents an excellent opportunity for reducing emissions through a switch to climate-friendly building design. But how does Aotearoa New Zealand achieve sustainable, low carbon emission buildings when there's also a pressing need to improve seismic resilience?

This is the question that Charlotte Toma and Max Stephens of University of Auckland Waipapa Taumata Rau have been exploring recently. The social and economic fallout of the 2011 Christchurch Earthquake has driven a desire for buildings that are not only safe to evacuate from, but also functional after earthquakes. Typically, for commercial buildings, that would mean using more high carbon footprint materials like concrete and steel, thereby coming at a cost to the climate. However, with an investigation into the carbon emissions associated with the Canterbury earthquakes, the researchers have demonstrated that not increasing our seismic resilience also has costs for the climate.

About 1,400 commercial buildings were demolished after the 2011 Christchurch Earthquake. The researchers took a subset of 142 concrete buildings and worked out the carbon footprint of their demolition and replacement. It came to the equivalent of 303,608 tonnes of carbon dioxide – to offset these emissions approximately five million tree seedlings would have to grow for ten years. Clearly, buildings being destroyed before the end of their useful life is not good for the climate. Max would like to design buildings that never fall down, but he knows that would come at too high a carbon cost. Charlotte is adamant we need to be reducing the up-front carbon cost of buildings. Together they argue that sustainability and seismic resilience must work hand in hand – that there are clever ways to obtain better seismic performance without dramatically increasing carbon emissions.

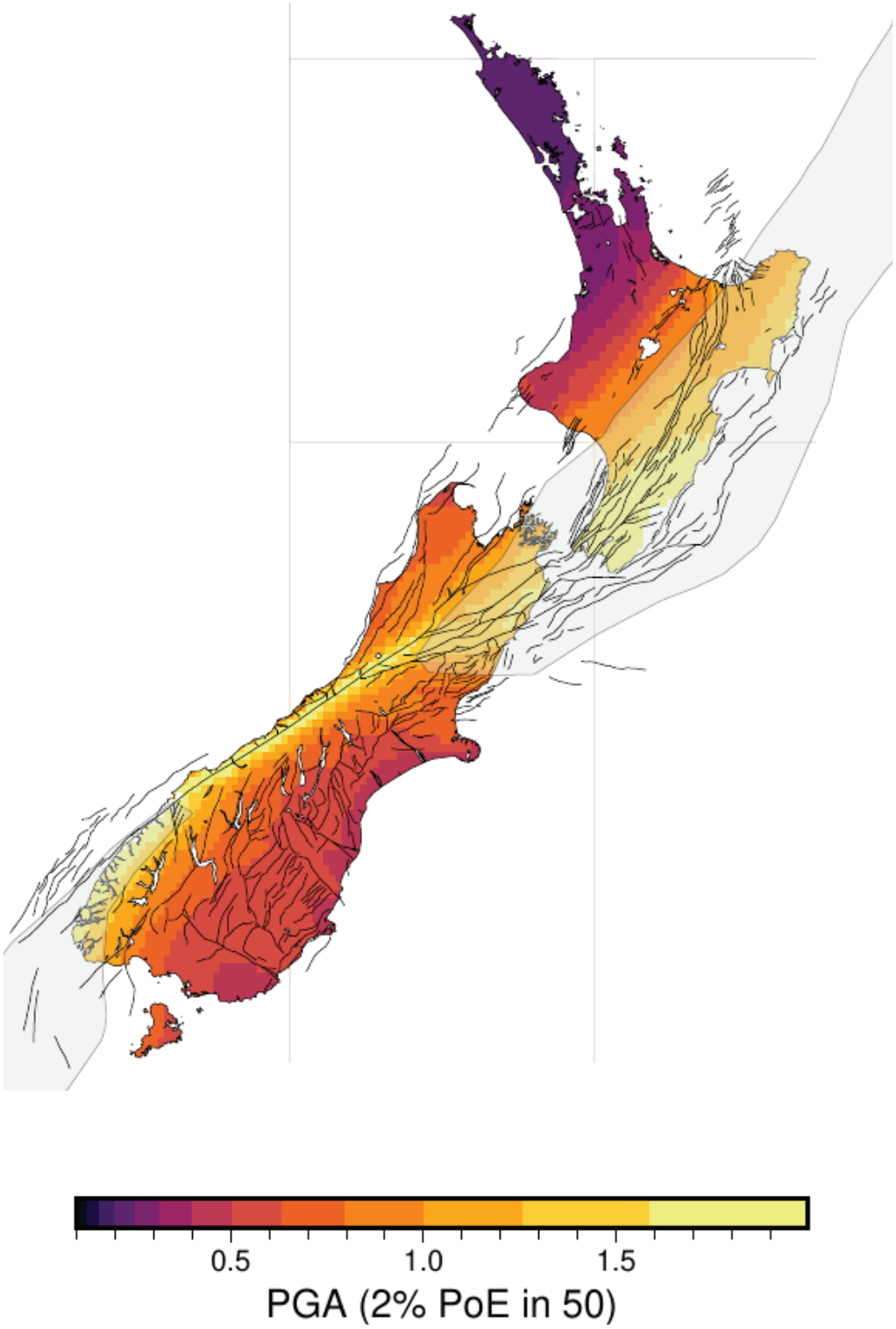
The researchers have now developed a framework to incorporate environmental impacts into seismic design decisions. Much of this work has been undertaken by Rosa Gonzalez for a PhD funded by BRANZ and Te Hiranga Rū QuakeCoRE. Charlotte and Max agree that they need more students like Rosa – there's a complex set of skills required to find structural engineering solutions that balance local seismic hazard considerations and global climate drivers. And Aotearoa New Zealand is going to need more of this work to reach our target of reducing greenhouse gas emissions by 50% in the next seven years.

Quantifying Earthquake Hazard: Innovation Meets Rigour

There's a balancing act at play in scientific endeavour: The desire to do something that's never been done before and the practical need to keep things grounded in reality. The creation of Te Tauira Matapae Pūmate Rū i Aotearoa, New Zealand's National Seismic Hazard Model (NSHM) 2022, struck an excellent balance.

Innovation led the way in the development of models and processes for updating Aotearoa New Zealand's best estimate for where, how big, and how often the ground will shake in future earthquakes. With funding from the Ministry of Business, Innovation, and Employment and Toka Tū Ake EQC, scientists from Crown Research Institutes and tertiary institutions were free to collaborate and innovate. Individual segments of faults became interconnected structures capable of complex multi-fault ruptures. A single, simple ground motion model became an interplay of numerous advanced alternatives. The resulting update not only caught up with current practice internationally, but also leap-frogged ahead in several areas. The related research has been accepted in academic spheres with over 30 peer-reviewed articles published in scientific journals.

Research centering around the 2022 Aotearoa New Zealand National Seismic Hazard Model formed the basis for two special issues of the Seismological Society of America.



When working with data that's ultimately going to influence engineering design and construction standards, land-use planning, insurance policies, risk assessments, and community resilience strategies, it's wise not to head too far off into the wide blue yonder of innovation. Model results need to robustly approximate the truth. This is where expert judgement comes into play. Specific approaches were used to minimise bias while making the most of expert judgement. This formally structured treatment of individuals' advice helped to produce a rigorous analysis of seismic hazard for Aotearoa New Zealand.

Seismic hazard estimates increased, on average, by 50% in this latest iteration of the model compared with the 2010 version. This has significant social and economic implications and yet the model has been well received. People may not be happy about the implications of the higher hazard estimates, but they are confident in the results. The balance of innovation and robust process that makes up NSHM 2022, and the widespread collaboration and consultation, has resulted in a piece of work that people trust.

Te Hiranga Rū QuakeCoRE has been part of the balancing act. With numerous investigators on both sides of the model – working on the underpinning science as well as the implementation of results into practice – they have helped ensure that NSHM 2022 consists of innovative research grounded in scientific rigour.

This map shows the **strength** of shaking and **how likely** it is that this level of shaking will occur within the next 50 years. The dark purple colours are weak shaking and the light orange and yellow colours are strong shaking. The scale bar shows peak ground acceleration (PGA) measured in g (1g is equal to gravitational acceleration on Earth). The thin black lines and grey shaded areas show the faults and subduction zones (respectively) that went into creating the model.

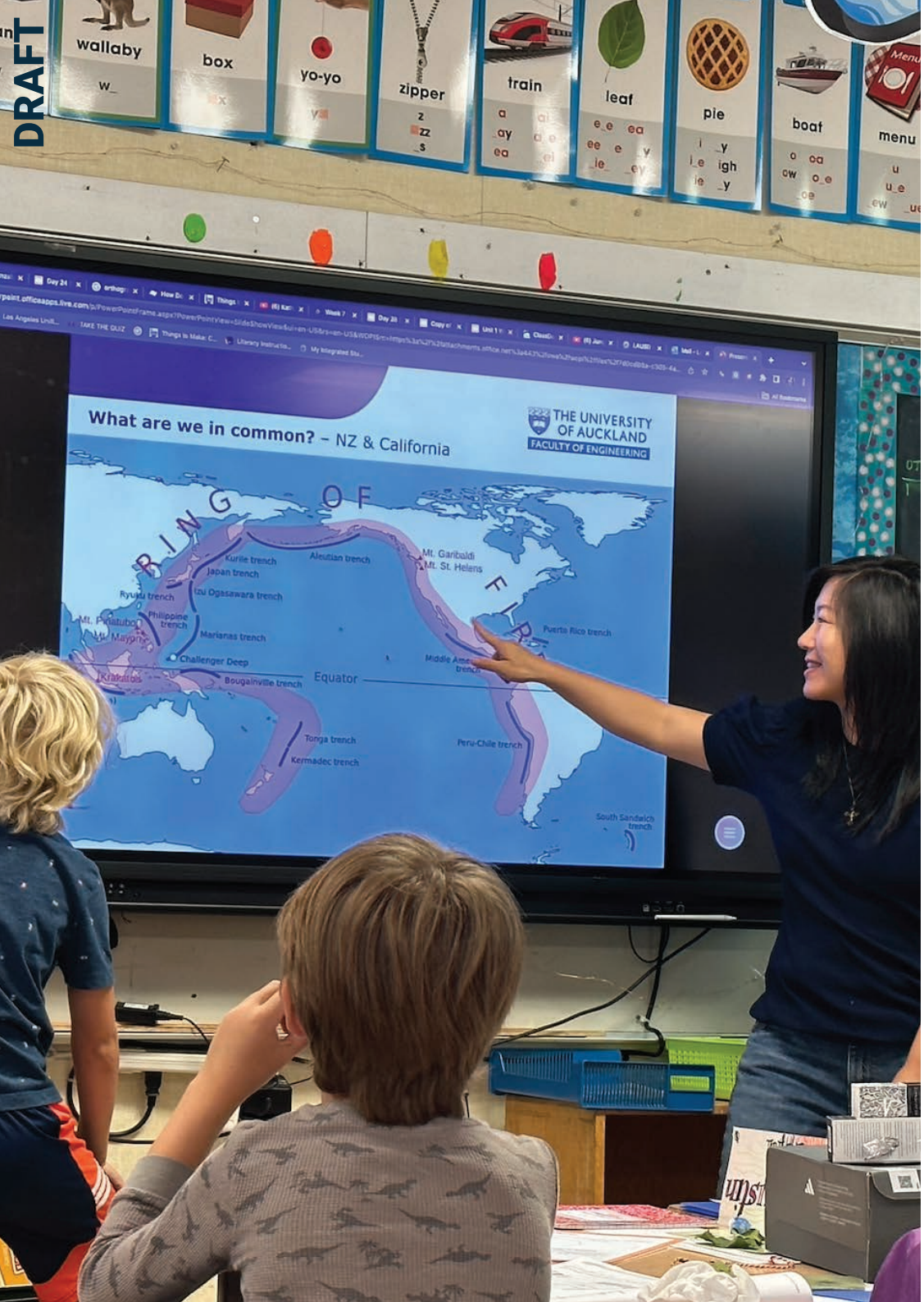
There is a 2% chance of experiencing this level of shaking in the next 50 years. Image supplied.

Building to Minimise Disruption after Earthquakes

Aotearoa New Zealand's building code has, understandably, had a strong emphasis on structural standards that safeguard people from injury and death. But there are additional aspirations that would help our seismically active country avoid being knocked back every time the crust tears beneath our feet. Imagine the recovery from the 2011 Christchurch Earthquake if, instead of demolishing thousands of buildings, we'd been able to immediately reuse or repair most of them. A quick recovery for buildings would mean a quick recovery for businesses and a huge reduction in the social, economic, and environmental toll of earthquakes.

"We need to be ready for Alpine Fault and Hikurangi Subduction Zone earthquakes and there is still much to learn from past events, nationally and internationally". Alice Chang-Richards of University of Auckland Waipapa Taumata Rau is determined to use past events to inform a better future. For example, what level of building performance is appropriate? What timeframes for restoring function do we want? And how should these factors be integrated into the building code? Research to help answer these questions is underway as part of Te Hiranga Rū QuakeCoRE's Interdisciplinary Programme 1, which Alice co-leads with Geoff Rodgers of University of Canterbury Te Whare Wānanga o Waitaha.

Alice at the Northridge Earthquake recovery case study building: Trinity Church, a community central hub in San Fernando which was severely damaged in the 1994 Northridge Earthquake. Photo supplied.



Meanwhile, Alice has been in California where this process is underway – a move from a focus on life safety to one of functional recovery for buildings. Alice received a Fulbright New Zealand Scholar Award in 2023 for which she was hosted by Henry Burton at the University of California, Los Angeles. The Fulbright project was to examine and simulate building recovery trajectories following the 1994 Northridge Earthquake – the 30th anniversary of which she was there to mark. She also had the opportunity to be a corresponding member of a Functional Recovery Task Committee run by FEMA's National Earthquake Hazards Reduction Program to learn about the seismic codification process in America.

Back in Aotearoa New Zealand, Alice is building an agent-based model that will simulate decision making for post-earthquake recovery. Case studies from Northridge and Ōtautahi Christchurch have illustrated how intertwined business disruption is with community recovery. There are many interdependencies that can lead to bottlenecks in recovery. "The vulnerability or resilience of one building affects that of nearby buildings so, if we can model a network of buildings, we can be more strategic about how we recover and thereby minimise disruption", says Alice.

Alice sharing her knowledge of earthquake engineering with a class at Fairburn Avenue Elementary School in Los Angeles as part of her Fulbright Scholarship. Photo supplied.

Collaboration for Impact

CEISMIC: A Treasure Trove of the Canterbury Earthquakes

At 12.51pm on Tuesday 22 February 2011, English professor Paul Millar had just finished teaching his first honours-level seminar in digital humanities at University of Canterbury Te Whare Wānanga o Waitaha. He was excited to be building capability in a discipline he'd been spearheading for some time. The M6.2 earthquake that struck Ōtautahi Christchurch at that moment, stopped all plans in their tracks. In the weeks that followed the devastating earthquake, Paul watched his engineering and geoscience colleagues being useful as part of the disaster response, and he felt powerless.

With a suggestion from his friend James Smithies, and a point towards the digital archives that were collected after the attacks on the World Trade Centre in New York in 2001, Paul found his outlet for helping to alleviate the trouble Cantabrians found themselves in. In the chaos after disasters there's an exponential increase in content creation and usually only very chaotic attempts to collect it, let alone archive it. So, with his digital humanities hat on, Paul stepped in with a solution, and the University of Canterbury Te Whare Wānanga o Waitaha agreed to fund it: CEISMIC – The Canterbury Earthquakes Digital Archive.

CEISMIC is an open access repository of 200,000 items related to the Canterbury Earthquake Sequence. With no stipulations as to what should be collected, everything from backyard photos, children's drawings, personal stories, to official documents from the numerous agencies responding to the earthquakes, came flying in. The database was designed to accommodate vast amounts of material from diverse sources making for an unprecedented collection that includes many insights from outside of the official narratives.

Collaboration has been at the heart of the success of CEISMIC. From the beginning, a consortium was formed of agencies with mandates to preserve material of cultural interest. Working together ensured they maximised, rather than duplicated, collection efforts. More recently, Te Hiranga Rū QuakeCoRE has partnered with CEISMIC to boost its accessibility for researchers. The backend of the database has been upgraded, there's a planned refresh for the frontend, and tagging of items of relevance for QuakeCoRE research is ongoing.

For some Cantabrians, CEISMIC has been a therapeutic tool – it's like a memory box of things lost, a collective record of tough times overcome. But far from being a passive repository, Paul hopes it remains an active resource for catalysing and feeding the creation of new knowledge that makes a difference.

Supporting Critical Infrastructure in Extreme Weather

The summer of early 2023 brought weather-inflicted havoc to the North Island: Cyclone Gabrielle will be Aotearoa New Zealand's costliest non-seismic hazard event ever. In the cyclone's wake, damage to critical infrastructure left communities isolated and without essential services. So, in response to the Ministry of Business, Innovation and Employment's funding for extreme weather science, Liam Wotherspoon of University of Auckland Waipapa Taumata Rau and Charlotte Brown of Resilient Organisations called on their networks to contribute to the unfolding situation.

Coming from a multidisciplinary, multi-institutional, and well-connected community, Te Hiranga Rū QuakeCoRE researchers are well placed to offer leadership in the face of challenges to infrastructure. Past disaster events, both nationally and internationally, have given them relevant experience. Liam and Charlotte, representing a team of researchers, set to work to gather information and provide advice regarding critical infrastructure damage.

Firstly, to inform the ongoing recovery, insights were gathered from international best practice and two policy briefings were prepared. One outlined the key lessons on critical infrastructure recovery derived from 14 major natural hazard events around the world. The other provided a checklist to help decision-makers integrate resilience into the rebuilding of infrastructure and to inform investment decisions.

The remains of the damaged Hikuwai Bridge on State Highway 35 in Tairāwhiti Gisborne and the temporary Bailey Bridge. Image credit: Liam Wotherspoon.

Secondly, spatial and temporal data was collected to provide a comprehensive picture of the damage to critical infrastructure and the levels of service available over time. The overall aim was to obtain the evidence required to better understand how Aotearoa New Zealand's critical infrastructure systems work as an integrated whole – water, power, telecommunication, transportation – and how they can be improved to better withstand future events. The data is also hugely valuable for individual providers; to help them understand dependencies and build more resilient networks.

Collaboration was key to the success of this work. Roger Fairclough, Chair of the New Zealand Lifelines Council, was instrumental in facilitating relationships with providers. Infrastructure agencies fed data into the project despite being very busy in disaster recovery mode. Students did much of the work. The resulting database will be one of the most complete sets of post-event data ever collected in Aotearoa New Zealand. Liam and Charlotte are pleased that this work provides extensive, real-world evidence that will help us to better value the building of resilience into the critical services that support our communities.

Example of the status of the road network in Tairāwhiti Gisborne a few weeks after Cyclone Gabrielle.
Red= closed
Yellow= reduced service.
Image credit: Liam Wotherspoon.

Kura Preparedness for Natural Hazards

Tamariki (children) may be some of the most vulnerable members of society when it comes to facing natural hazards, but they are also some of the most powerful because of their ability to learn and adapt and bring communities along with them. Tamariki of Te Tairāwhiti Gisborne and the Waiāriki area are particularly exposed to potential impacts from natural hazards given their location on Aotearoa New Zealand's northeastern coast, immediately adjacent to the Hikurangi Subduction Zone. Te Hiranga Rū QuakeCoRE social scientists have been working with kura (schools) in these regions to better understand how to enhance preparedness for, and responses to, earthquakes and tsunamis.

Kelvin Tapuke, Lucy Kaiser, and David Johnston of the Joint Centre for Disaster Research at Massey University Te Kunenga ki Pūrehuroa have been visiting schools and holding hui (meetings) with staff members to explore what further information or resources are required to boost resilience. Seven to ten kura have been visited each year over the last three years. Topics discussed include tsunami evacuation zones, practice evacuations, response plans at home and at school, stakeholder involvement, and development of resources and capability.

Teaching Principal Karla Kohatu (centre), Hatea-a-Rangi School, Tokomaru Bay, with QuakeCoRE Researchers Lucy Kaiser and Kelvin Tapuke. Image credit: David Johnston.

The researchers found that school communities had long-standing knowledge of earthquake and tsunami risk, experience from past events, and a wide range of approaches to managing risk in future events. Some communities were well practised at being isolated and had resources and skills to keep themselves self-sufficient for some time after a disaster. However, all the schools were keen to continue exploring opportunities with the researchers for building their emergency preparedness.

Initiatives underway include the co-development of response plans, maps and signage to aid evacuation, collaborative creation of care kits for each student, and supporting leaders to access financial assistance for building capability. Schools have focused on boosting the importance of tsunami evacuations in their communities and adapting the curriculum to introduce a caring approach rather than a fear-based approach in responding to hazard events.

Building resilience is a collaborative process. Community elders have provided crucial support for this research and relationships have been key to its success. The more that researchers and local emergency managers are involved in community activities, and responsive to differing priorities, the more likely community resilience will improve. And what the researchers and communities both want, is for the tamariki of today to become the leaders of tomorrow in ensuring that everyone is safe in the face of natural hazards.

Tamariki at Te Kura ā-Iwi o Tōrere practicing “taka, uhi, mau tonu” (drop, cover and hold) as part of the programme to build resilience in the community. Photo credit: David Johnston.

Human Capability Development

Bringing Home Seismic Protection Insights

Ten steps away from the desk where he wrote his PhD thesis, Alex Shegay has a new desk. He is now a lecturer in the Civil and Environmental Engineering Department at University of Auckland Waipapa Taumata Rau. Alex is enjoying the fact that, "the people who used to teach me are now my colleagues". But far from staying in the same department all his career, Alex advocates travel as essential for "opening up the mind and becoming a well-rounded researcher".

During his PhD on the seismic performance of reinforced concrete walls, Alex received a Fulbright-EQC Graduate Award in Natural Disaster Research. This gave him the opportunity to spend a year at the University of Washington learning from American professors with experience in seismic testing and computer modelling. After his PhD, he headed to Japan.

Alex went to Sendai as a postdoctoral fellow and then got a job in Tokyo as an assistant professor. During his four years in Japan he learnt the language, witnessed the recovery from the 2011 Tōhoku Earthquake, experienced several magnitude seven earthquakes, and was involved with research into the seismic performance of reinforced concrete buildings, the design of dampers and base isolators, and the strain ageing characteristics of reinforcing steel.

One of Alex's goals for his time in Japan, was to introduce Japanese research (often published in Japanese) to other countries so they could benefit from Japan's extensive experience in earthquake protective technology. Now that he's back in Aotearoa New Zealand, he is seeing that goal come to fruition with a Royal Society Catalyst: Seeding Grant enabling Japanese and Aotearoa New Zealand colleagues to work together on solutions for retrofitting buildings with modern seismic protection systems.

Te Hiranga Rū QuakeCoRE has been following Alex from the beginning. He remembers back to the start of his PhD in 2015 when his supervisor, Ken Elwood, was extra busy – working to establish QuakeCoRE. Alex received a QuakeCoRE scholarship to fund the completion of his PhD and was also employed by QuakeCoRE to train researchers in how to use the "DesignSafe-Cyberinfrastructure" platform. Now he's involved in QuakeCoRE research, leading the effort of designing the test plan for internal components in buildings undergoing shake table tests.

Alex encourages students to, "seek opportunities to spend time overseas – when you come back you'll bring new ideas and, perhaps more importantly, new networks. For a small country like New Zealand, such networks are essential."

Alex standing in front of a collapsed 10-storey building in Türkiye. The photo was taken on an earthquake damage reconnaissance mission following the 2023 Türkiye Earthquake, in collaboration with colleagues from Japan and Türkiye. Photo supplied.

Stepping Stones into a Research Career

Just as fledgling birds require parental care while they build up the feathers and wing muscles for flight, early career researchers require support to get to the point where their careers can take off. Te Hiranga Rū QuakeCoRE's Proposal Development Grants provide this kind of support. Designed to enable data collection, analysis, or team building for the purpose of generating strong proposals for other research funds, the grants are targeted at scientists who are less than seven years post PhD.

Katherine Yates worked as a consultant engineering geologist before following her curiosity into a PhD at University of Canterbury Te Whare Wānanga o Waitaha. She wanted to find out more about the strength of a common soil type on the hills around Ōtautahi Christchurch. Loess is made of dust from windblown rock fragments and can be quite strong, but it weakens when wet and can fall apart suddenly. Katherine studied the shear strength of loess soils as they get wetter. After completing her PhD, she was still curious: In our seismically active country, with increasing extreme weather from climate change, how would loess respond to being wet and shaken?

Katherine's mentor, Gabriele Chiaro, encouraged her to apply for a QuakeCoRE Proposal Development Grant. Katherine says it was a perfect stepping stone, "It was nice to have a short, supportive process unlike the bigger grant applications which can be quite confronting.

Katherine excavating loess samples and field instrumentation equipment in Takamatua, Akaroa Harbour. Photo supplied.

The development grant gave me valuable experience in practical research skills like turning thoughts into proposals, budgeting, and managing a small project". Research-wise it enabled Katherine to fund student assistance in the laboratory, write a conference paper, and travel to Japan for the 8th International Conference on Earthquake Geotechnical Engineering in late 2024.

As it turns out, the ideas that went into the QuakeCoRE application acted as stepping stones for a successful postdoctoral fellowship application to the Rutherford Foundation. Katherine is now able to continue her research into loess and the implications for slope stability. She is also branching out to look at other soils vulnerable to weakening with rainfall, thanks to a Toka Tū Ake EQC Biennial Grant. And the Whaka-Ora Healthy Harbour initiative is using her expertise to investigate erosion of loess into Whakaraupō Lyttleton Harbour at Rāpaki. Perhaps her next stepping stone will be a Marsden Fund Fast-Start Grant but, for now, she has enough support to facilitate a busy research schedule.

Katherine preparing materials in the University of Canterbury Te Whare Wānanga o Waitaha Geomechanics Laboratory. Photo supplied.

Network for Early Career Researchers

Fresh perspectives, new skills, increased diversity, and the energy of youth are some of the key assets that early career researchers bring to any research community. They promote growth and ensure the longevity of the scientific field they're involved in. But, emerging from the relative safety of postgraduate study into the real world and wanting to earn a living as a researcher, can be daunting.

Te Hiranga Rū QuakeCoRE Programme Area Leaders Tim Stahl and Alice Chang-Richards remember navigating those early career years and are keen to provide more support for others. Tim explains, "QuakeCoRE has a strong network of QuakeCoRE Student Chapters (QSC), but we realised there's a gap – there's nowhere to go for support once you finish studying". So, along with Tim Sullivan, they submitted a white paper to the QuakeCoRE Directors proposing the establishment of an Early Career Researchers' (ECR) Network.

The proposal was approved and there's now an Establishment Committee of seven researchers across Aotearoa New Zealand working to develop the structure and function of the network. Activities so far include a survey of QuakeCoRE members to ascertain what researchers want, a Slack channel for communicating, a breakfast at QuakeCoRE's Annual Meeting in 2023, and a webinar by Jack Baker of Stanford University. About 40 people attended the breakfast and enjoyed talks on various topics including preparing funding applications, team building and project management, as well as tips for building personal resilience. Tim and Alice both wish they'd had something like this when they started out.

Officially, ECRs are those who are active researchers and only seven to ten years on from their highest qualification (excluding periods of leave). If postgraduate students are the seedlings of the research forest, then ECRs are the saplings. It is still a potentially vulnerable time, so there's good sense in having a network to foster a sense of connection, encourage peer support and collaboration, and establish mentorships.

For QuakeCoRE, ECRs represent potential for upskilling into in-demand niches and future leadership roles. Mentoring of such researchers can be the ultimate in succession planning. The International Science Advisory Board for QuakeCoRE commented that the ECR Network is a positive development that will help grow capability and leadership. The initiative is set to provide a more welcoming and communal experience for ECRs, and a stronger workforce for QuakeCoRE to continue its mission of transforming the earthquake resilience of society.

Tim Stahl presenting at the Early Career Researcher Network breakfast at the QuakeCoRE 2023 Annual Meeting.
Photo supplied.

Recognition Highlights

Lauren Vinnell

(Massey University Te Kunenga ki Pūrehuroa)

In April Lauren Vinnell, Piata Inch, David Johnston and Nick Horspool received the prestigious Earthquake Engineering Research Institute (EERI) 2022 Outstanding Paper Award in San Francisco. The Outstanding Paper Award is awarded to authors of Earthquake Spectra papers judged to be outstanding contributions to earthquake hazard mitigation. The multi-disciplinary team's work analysing CCTV footage to establish what people actually did during the 2016 Kaikōura Earthquake was recognised as being a novel research approach which compliments other more traditional data-gathering methodologies.

Jack Baker, Editor in Chief of *Earthquake Spectra* with Lauren Vinnell and David Johnston at the EERI 2023 Annual Meeting. Photo supplied.

Santiago Pujol

(University of Canterbury Te Whare Wānanga o Waitaha)

Santiago Pujol was honoured with the American Concrete Institute's Arthur J. Boase Award. Established in 1971, the award is given in recognition of outstanding research and contributions to the structural concrete field. The award acknowledges Santiago's work focusing on the use of high-strength steel in reinforced concrete members which provides more cost-effective construction solutions for buildings designed to resist earthquake motions.

Santiago in the Structural Lab developing innovative retrofit systems.
Photo Credit: University of Canterbury Te Whare Wānanga o Waitaha.

New Zealand Society for Earthquake Engineering Recognitions

In 2023, Te Hiranga Rū QuakeCoRE researchers were acknowledged by the New Zealand Society for Earthquake Engineering (NZSEE) with various awards and recognitions:

- Lucas Hogan received the Toka Tū Ake EQC / NZSEE Ivan Skinner Award for the advancement of earthquake engineering research.
- Riwaj (Ribu) Dhakal, Misko Cubrinovski and Christopher de la Torre together with international collaborator Jonathan Bray were awarded the Otto Glogau award for their paper “Liquefaction assessment of reclaimed land at Centreport, Wellington". This award is offered annually to the best publication during the past three years; not only had the paper been frequently referenced but it was also recognised for the rigour and innovative research methods used.
- Greg MacRae was elected as a Fellow of NZSEE for his services to earthquake engineering in Aotearoa New Zealand and Industry Affiliate Des Bull was conferred a Life Membership for his services to earthquake engineering, structural engineering and Urban Search and Rescue in Aotearoa New Zealand.
- Charlotte Toma alongside Industry Affiliate Patrick Cummuskey, and Annie Scott and Elly Rishworth were awarded the NZSEE President’s Award for their work on the Advancing Women in Engineering and Construction Team.
- QuakeCoRE researchers also received a number of paper and poster awards including Best Research Paper (Catalina Miranda), Best Poster (Soheil Assadi), Best Conference Paper (Ashkan Hashemi, Pierre Quenneville, Charles Clifton, James Lim & Shahab Ramhormozian).

Fellowships

Te Hiranga Rū QuakeCoRE researchers were awarded a number of fellowships, including:

- Brendon Bradley was elected as a Fellow Royal Society of New Zealand Te Apārangi.
- Jason Ingham was elected as a Fellow of the UK Institution of Structural Engineering.
- Matthew Hughes received a MBIE Ngā Puanga Pūtaiao Fellowship.
- Tom Logan received a Royal Society of New Zealand Te Apārangi Rutherford Discovery Fellowship.

Other Recognitions

Two Te Hiranga Rū QuakeCoRE researchers were awarded Fulbright New Zealand Scholar Award

- Alice Chang-Richards
- Siautu Alefaio-Tugia

Financials, Community & Outputs

Financials

Category	Total ($000s)
CoRE Funding	4,200
Total Revenue	**4,200**
Directors and Principal Investigators	243
Associate Investigators	0
Postdoctoral Fellows	117
Research Assistants	140
Others	181
Total Salaries & Salary-related Costs	**681**
Overheads	698
Project Costs	932
Travel	369
Postgraduate Students	1,512
Equipment Depreciation / Rental	0
Subcontractor(s)	0
Total Other Costs	**3,511**
Total Expenditure	**4,192**
Net Surplus / (Deficit)	**8**

2023 at a glance

Category	Detailed category	FTE	Count
People	Principal Investigators	1.47	23
	Associate Investigators	0.00	92
	Postdoctoral Fellows	1.20	5
	Research Technicians	1.35	6
	Administration/Support	2.73	3
	Research Students	93.33	121
	Total	**100.08**	**250**
Peer-reviewed research outputs	Books		0
	Book Chapters		2
	Journal Articles		101
	Conference Proceedings		38
	Total		**141**
Commercial activities	Number of Licenses		0
	Patent Applications		0
Students studying at CoRE by level	Doctoral Degree		94
	Masters		26
	Other		1
	Total		**121**

Community

115
Investigators

30
Industry Affiliates

17
Affiliate Organisations

Board

Mike Mendonça (Chair)	
David Brunsdon	Kestrel Group
Richard Clarke	University of Auckland
Ellen Rathje	University of Texas at Austin
Wendy Saunders	Toka Tū Ake EQC
Tā Mark Solomon	
Ian Wright / Peter Gostomski	University of Canterbury

International Science Advisory Panel

Ellen Rathje (Chair)	University of Texas at Austin
Jack Baker	Stanford University
Ann Bostrom	University of Washington
Shyh-Jiann Hwang	National Taiwan University
Juan Carlos de la Llera	Pontificia Universidad Católica de Chile

Directors

Brendon Bradley (Director)	University of Canterbury
David Johnston (Deputy Director)	Massey University
Anthony Hoete (Pouwhakahaere)	University of Auckland
Caroline Orchiston (Associate Director)	University of Otago
Kelvin Tapuke (Pouwhakahaere)	Massey University
Liam Wotherspoon (Associate Director)	University of Auckland

Principal Investigators

Julia Becker	Massey University
Brendon Bradley	University of Canterbury
Charlotte Brown	Resilient Organisations
Alice Chang-Richards	University of Auckland
Tūmanako Fa'aui	University of Auckland
Olga Filippova	University of Auckland
Rick Henry	University of Auckland
Anthony Hoete	University of Auckland
John Hopkins	University of Canterbury
Jason Ingham	University of Auckland
David Johnston	Massey University
Christine Kenney	Massey University
Garry McDonald	Market Economics Research
Nirmal Nair	University of Auckland
Ilan Noy	Victoria University of Wellington
Caroline Orchiston	University of Otago
Rolando Orense	University of Auckland
Santiago Pujol	University of Canterbury
Geoff Rodgers	University of Canterbury
Tim Stahl	University of Canterbury
Tim Sullivan	University of Canterbury
Liam Wotherspoon	University of Auckland

Associate Investigators

Ho Seok Ahn	University of Auckland
Esther Aigwi	Auckland University of Technology (AUT)
Siautu Alefaio-Tugia	University of Otago
Hamish Avery	University of Canterbury
Natalie Baird	University of Canterbury
Sherif Beskhyroun	Auckland University of Technology (AUT)
Denise Blake	Victoria University of Wellington
Megan Boston	University of Waikato
Anna Brown	Massey University
Robert Cardwell	Market Economics Research
David Carradine	BRANZ
Reagan Chandramohan	University of Canterbury
Victoria Chanse	Victoria University of Wellington
Gabriele Chiaro	University of Canterbury
Charles Clifton	University of Auckland
Mary Anne Clive	GNS Science
Toni Collins	University of Canterbury
Seosamh Costello	University of Auckland
Nicholas Cradock-Henry	Lincoln University
Kim de Graaf	University of Waikato
Chris de la Torre	University of Canterbury
Enrique del Rey Castillo	University of Auckland
David Dempsey	University of Canterbury
Rajesh Dhakal	University of Canterbury
Ken Elwood	University of Auckland
Clark Fenton	University of Canterbury
Joanna Fountain	Lincoln University
Matt Gerstenberger	GNS Science
Lesley Gray	University of Otago
Emily Harvey	Market Economics Research
Ashkan Hashemi	University of Auckland
Tracy Hatton	Resilient Organisations
Lucas Hogan	University of Auckland
Nicolas Horspool	GNS Science
Andy Howell	GNS Science
Emma Hudson-Doyle	Massey University
Matthew Hughes	University of Canterbury
Anne Hulsey	University of Auckland
Finnigan Illsley-Kemp	Victoria University of Wellington
Minh Kieu	University of Auckland
Robert Langridge	GNS Science
Chin-Long Lee	University of Canterbury
Robin Lee	University of Canterbury
Cécile L'Hermitte	University of Waikato
Rebecca Lilley	University of Otago
Nicola Litchfield	GNS Science
James Lim	University of Waikato
Angela Liu	BRANZ
Tom Logan	University of Canterbury
Giuseppe Loporcaro	University of Canterbury
Quincy Ma	University of Auckland
Gregory MacRae	University of Canterbury
Sanna Malinen	University of Canterbury
Annick Masselot	University of Canterbury
Chris Massey	GNS Science
John McClure	Victoria University of Wellington
Samuel McColl	GNS Science
Nicola McDonald	Market Economics Research
Christopher McGann	University of Canterbury

Mark Milke	University of Canterbury
Paul Millar	University of Canterbury
Maxim Millen	University of Canterbury
Camilla Penney	University of Canterbury
Raj Prasanna	Massey University
Pierre Quenneville	University of Auckland
Shahab Ramhormozian	Auckland University of Technology (AUT)
Prakash Ranjitkar	University of Auckland
Sean Rees	University of Canterbury
Thomas Robinson	University of Canterbury
Krishanu Roy	University of Waikato
Vinod Sadashiva	Massey University
Allan Scott	University of Canterbury
Max Stephens	University of Auckland
Timothy Stern	Victoria University of Wellington
Carol Stewart	Massey University
Mark Stirling	University of Otago
Kristin Stock	Massey University
Andrew Stolte	University of Auckland
Mark Stringer	University of Canterbury
Marion Tan	Massey University
Charlotte Toma	University of Auckland
Nadia Trent	University of Waikato
SR Uma	GNS Science
Lauren Vinnell	Massey University
Priya Vishnu	Massey University
Kevin Wang	University of Auckland
Colin Whittaker	University of Auckland
Thomas Wilson	University of Canterbury
Katherine Yates	University of Canterbury
Fei Ying	Massey University
Pouyan Zarnani	Victoria University of Wellington
Conrad Zorn	University of Auckland

Industry Affiliates

Sarah Barrett	Beca
Derek Baxter	Wellington City Council
Jeff Bayless	AECOM
Nicholas Brooke	Compusoft Engineering
Dave Brunsdon	Kestrel Group
Des Bull	Holmes Consulting
Nigel Colenso	ABI Piers
Patrick Cummuskey	Auckland Council
Michael Drayton	Risk Management Solutions
Paul Drummond	CSI Limited
Roger Fairclough	Neo Leaf Global
Helen Ferner	NZSEE
Jeff Fraser	Golder Associates
Reza Jafarzadeh	Auckland Council
Jared Keen	Beca
Ajay Makhija	NEMA
Gareth Morris	Holmes Consulting
Stuart Oliver	Holmes Consulting
Aasha Pancha	Aurecon
Didier Pettinga	Holmes Consulting
Dario Pietra	Holmes Consulting
Andrew Renton	Transpower
Romy Ridl	KiwiRail
Wendy Saunders	Toka Tū Ake EQC
Andreas Skarlatoudis	AECOM
Paul Somerville	AECOM
Erin Todd	Golder Associates / WSP
Sjoerd Van Ballegooy	Tonkin + Taylor
Rick Wentz	Wentz Pacific
Stuart Woods	Waka Kotahi

Postdoctoral Fellows

In addition to the postdoctoral fellows listed below, there are a number of additional postdoctoral fellows that are part of the QuakeCoRE Community but funded with aligned funding.

Kieran Haymes	University of Canterbury
Will Pollalis	University of Canterbury
Marion Tan	Massey University
Jeremy Treadwell	University of Auckland
Lauren Vinnell	Massey University

Students

Prestige Scholarship Recipients

Our Prestige Scholarship Recipients have been awarded Te Hiranga Rū QuakeCoRE Scholarships as outstanding students to support postgraduate research under the supervision of a QuakeCoRE Investigator.

Brandy Alger	University of Canterbury
Niranjan Andige	Victoria University of Wellington
Caelan Church	University of Otago
Sameeah Hameed	Massey University
Beatrice Holman	University of Canterbury
Matthew Luani	Massey University
Kianoush Rostami	Massey University
Melanie Roundill	Victoria University of Wellington

Students

In addition to the students listed below that received direct support towards their postgraduate studies, there are a number of students engaged with our research programme that are funded with aligned funding.

Yousef Abdeljawad	Victoria University of Wellington
Shaila Arif	University of Auckland
Fransiscus Arifin	University of Canterbury
Leanne Avila	University of Canterbury
Annecy Bal	University of Auckland
Nicole Buck	University of Auckland
Angela Campbell	Victoria University of Wellington
Nainesh Chheda	University of Canterbury
Rahul Chopra	University of Auckland
Joshua Daglish	University of Canterbury
Max Dawson	University of Canterbury
Imogen Daysh	University of Canterbury
Michael Dupuis	University of Canterbury
Zane Egginton	University of Auckland
Akram Fatourehchishabestari	University of Auckland
Emma Gardiner	University of Canterbury
Laura Gnesko	University of Canterbury
Rosa Gonzalez	University of Auckland
Kasra Habibi	University of Auckland
Julia Harvey	University of Canterbury
Cansu Inal Kaynar	Victoria University of Wellington
Charles Kerby	University of Canterbury
Kaea Kerkin	University of Auckland
Anish Khadka	University of Auckland
Aiggan Kitila	University of Otago

Felipe Kuncar Garcia	University of Canterbury
Anna-Marei Kurei	University of Auckland
Charles Li	University of Auckland
Xin Liu	University of Auckland
Vahid Loghman	University of Canterbury
Pouya Lotfi Rad	University of Auckland
Hanna Lyford	University of Canterbury
Sarah Mabin	University of Canterbury
Bethany Mayer	University of Waikato
Nathan McDonald	University of Waikato
Catalina Miranda	University of Auckland
Richard Mowll	Massey University
Erin Murray (McEwan)	University of Canterbury
Sarah Neill	University of Canterbury
Sajan Neupane	Massey University
Sally Nkrumah	University of Auckland
Marie Claire Pascua	University of Auckland
Liam Pledger	University of Canterbury
Ariane Pola	University of Auckland
Macey Polwart	University of Canterbury
Yuping Qin	University of Waikato
Kiran Rangwani	University of Canterbury
Julian Rincon Gil	University of Canterbury
Kākati Royal	University of Canterbury
Claudio Schill	University of Canterbury
Juan Jose Sepulveda Garcia	University of Canterbury
Seyedamirhossein Shariati	University of Waikato
Charlie Sidey	University of Auckland
Julia Sit	University of Auckland
Vinu Sivakumar	University of Auckland
Emma Stucki	University of Waikato
Ayushi Tiwari	University of Canterbury
Shubham Tiwari	University of Waikato
Ren-Jie Tsai	University of Auckland
Abigail Underwood	University of Canterbury
Linxuan Wang	University of Canterbury
Latasha Wanoa	Massey University
Joshua Wight	University of Canterbury
Zhenduo Yan	University of Auckland
Majid Zakerinia	University of Auckland
Shen Zhan	University of Auckland

Other staff

Research Technicians

In addition to the Research Technicians listed below, there are a number of additional related roles that are supported with aligned funding.

Kasuni Adikari Appuhamilage	Massey University
Chanthujan Chandrakumar	Massey University
Georgina Gilchrist	Massey University
Lucy Kaiser	Massey University
Yuan Liu	University of Auckland
Kelvin Tapuke	Massey University

Support Staff

Ruth Hartshorn
Vicki Smith
Rosemary Walton

Partners

University of Canterbury (Host)
Auckland University of Technology (AUT)
BRANZ
GNS Science
Lincoln University
Market Economics Research
Massey University
Resilient Organisations
University of Auckland
University of Otago
University of Waikato
Victoria University of Wellington

Affiliate Organisations

Building Research Institute (BRI)	Tsukuba, Japan
Copenhagen Centre for Disaster Research (COPE)	Copenhagen, Denmark
DesignSafe	Austin, USA
EPICentre	London, UK
EU Centre	Pavia, Italy
Future Resilient Systems (FRS)	Singapore
Geotechnical Extreme Events Reconnaissance Association (GEER)	Atlanta, USA
International Joint Laboratory of Earthquake Engineering (ILEE)	Shanghai, China
Korea Institute of Science and Technology Information (KISTI)	Daegu, Korea
National Center for Research on Earthquake Engineering (NCREE)	Taipei, Taiwan
National Hazards Center (NHC)	Boulder, USA
National Hazards Engineering Research Infrastructure (NHERI) @UTexas	Austin, USA
National Hazards Engineering Research Infrastructure (NHERI) SimCenter	Berkeley, USA
Pacific Earthquake Engineering Research Center (PEER)	Berkeley, USA
Research Centre for Integrated Disaster Risk Management (CIGIDEN)	Santiago, Chile
Southern California Earthquake Center (SCEC)	Los Angeles, USA
Smart Structures Lab, Swinburne University of Technology	Melbourne, Australia

Publications

141
Direct Peer-reviewed Outputs

95
Annual Meeting Posters

Journal Publications (Direct Peer-reviewed)

Aigwi, I., Filippova, O., & Sullivan-Taylor, B. (2023) Public perception of heritage buildings in the city-centre of Invercargill, New Zealand. *City, Culture and Society,* **34**, 100538

Algiriyage, N., **Prasanna, R., Stock, K., Doyle, E.,** & **Johnston, D.** (2023) DEES: A real-time system for event extraction from disaster-related web text. *Social Network Analysis and Mining,* **13(1)**

Asadi, M., **Orense, R.,** Asadi, M., & Pender, M. (2023) Empirical assessment of liquefaction resistance of crushable pumiceous sand using shear wave velocity. *Journal of Geotechnical and Geoenvironmental Engineering,* **149(2)**, 4022132

Assadi, S., **Hashemi, A.**, & **Quenneville, P.** (2023) High performance rocking timber wall with innovative low-damage floor connections. *Structures,* **57**, 105075

Baki, M., Cubrinovski, M., **Stringer, M.,** van Ballegooy, S., & Ntritsos, N. (2023) Effects of partial saturation on the liquefaction resistance of sand and silty sand from Christchurch. *Soils and Foundations,* **63(6)**, 101400

Becker, J., Blake, D., Thompson, J., **Vinnell, L.,** & **Doyle, E.** (2023) Communicating evacuation information to multi-storey apartment dwellers: A case study of the 2016 Kaikōura Earthquake in Te Whanganui-a-Tara (Wellington), Aotearoa New Zealand. *New Zealand Journal of Geology and Geophysics,* **66(2)**, 177 – 191

Bhatta, J., **Dhakal, R.,** & **Sullivan, T.** (2023) Cyclic behaviour of two-story low-damage rocking precast concrete cladding panel system. *Journal of Earthquake Engineering,* **27(6)**, 1414 – 1439

Bhanu, V., **Chandramohan, R.,** & **Sullivan, T.** (2023) Drift-based risk-oriented method for the explicit consideration of ground motion duration in seismic design. *Earthquake Engineering and Structural Dynamics,* **52(13)**, 4009 – 4025

Bhatta, J., **Dhakal, R.,** & **Sullivan, T.** (2023) Seismic evaluation of rocking internal partition walls with dual-slot track under quasi-static cyclic drifts. *Journal of Earthquake Engineering,* **27(14)**, 4161 – 4181

Bhatta, J., **Dhakal, R.,** & **Sullivan, T.** (2023) Seismic performance of a rocking precast concrete cladding panel system under lateral cyclic displacement demands. *Journal of Earthquake Engineering,* **27(4)**, 929 – 958

Bhatta, J., **Dhakal, R., Sullivan, T.,** Bartlett, J., & Pring, G. (2023) Seismic performance of internal partition walls with slotted and bracketed head-tracks. *Journal of Earthquake Engineering,* **27(12)**, 3434 – 3470

Bhatta, J., **Dhakal, R.,** & **Sullivan, T.** (2023) Seismic performance of 'rocking' dual-slot track internal partition walls with concealed joints under lateral cyclic drift demands. *Journal of Earthquake Engineering,* **27(8)**, 2198 – 2223

Bloom, C., Singeisen, C., **Stahl, T., Howell, A.,** & **Massey, C.** (2023) Earthquake contributions to coastal cliff retreat. *Earth Surface Dynamics,* **11(4)**, 757 – 778

Bloom, C., Singeisen, C., **Stahl, T., Howell, A., Massey, C.,** & Mason, D. (2023) Coastal earthquake-induced landslide susceptibility during the 2016 Mw 7.8 Kaikōura Earthquake, New Zealand. *Natural Hazards and Earth System Sciences,* **23(9)**, 2987 – 3013

Bloom, C., **Stahl, T.,** & **Howell, A.** (2023) Distributed displacement on the Papatea Fault from the 2016 Mw 7.8 Kaikōura Earthquake and implications for hazard planning. *New Zealand Journal of Geology and Geophysics,* **66(2)**, 217 – 227

Bray, A., **Orchiston, C.,** & Shrestha, S. (2023) Using photovoice for disaster and hazard preparedness: A methodological review. *International Journal of Disaster Risk Reduction,* **93**, 103742

Brough, T., Nicol, A., **Stahl, T.,** Pettinga, J., Van Dissen, R., Clark, D., Khajavi, N., Pedley, K., **Langridge, R.,** & Wang, N. (2023) Paleoseismicity of the western Humps Fault on the Emu Plain, North Canterbury, New Zealand. *New Zealand Journal of Geology and Geophysics,* **66(2)**, 279 – 292

Brown, C., McDonald, N., McDonald, G., Daly, M., & Seville, E. (2023) Using an integrated dynamic economic model to support infrastructure investment decision-making. *Earthquake Spectra,* **39(4)**, 2644 – 2663

Chan, N., **Hashemi, A.,** Agarwal, S., **Zarnani, P.,** & **Quenneville, P.** (2023) Experimental testing of a rocking cross-laminated timber wall with pinching-free connectors. *Journal of Structural Engineering (United States),* **149(10)**, 4023132

Chan, N., **Hashemi, A., Zarnani, P.,** & **Quenneville, P.** (2023) Pinching-free connector in a self-centering braced frame. *Journal of Structural Engineering (United States),* **149(7)**, 4023083

Chandrakumar, C., **Tan, M.,** Holden, C., **Stephens, M.,** & **Prasanna, R.** (2023) Performance analysis of P-wave detection algorithms for a community-engaged earthquake early warning system–a case study of the 2022 M5.8 Cook Strait Earthquake. *New Zealand Journal of Geology and Geophysics,* 1–16

Charles, S., **Chang-Richards, A.,** & Yiu, T. (2023) Providing a framework for post-disaster resilience factors in buildings and infrastructure from end-users' perspectives: Case study in Caribbean island states. *International Journal of Disaster Resilience in the Built Environment,* **14(3)**, 366 – 389

Chaudhari, T., **MacRae, G.,** Bull, D., **Clifton, C.,** & Hicks, S. (2023) A simple mechanical model for steel beam–column slab subassembly nonlinear cyclic behaviour. *Journal of Earthquake Engineering,* **27(12)**, 3518 – 3535

Chiaro, G., Palermo, A., Banasiak, L., Tasalloti, A., Granello, G., & Hernandez, E. (2023) Seismic response of low-rise buildings with eco-rubber geotechnical seismic isolation (ERGSI) foundation system: Numerical investigation. *Bulletin of Earthquake Engineering,* **21(8)**, 3797 – 3821

Chigullapally, P., **Wotherspoon, L., Stephens, M.,** & **Hogan, L.** (2023) Recorded and modeled response of the Thorndon Overbridge during multiple earthquakes. *Earthquake Spectra,* **39(4)**, 2019 – 2041

De Francesco, G., & **Sullivan, T.** (2023) Accounting for hysteretic characteristics in P-Delta analysis of structures. *Earthquake Engineering and Structural Dynamics,* **52(15)**, 4919 – 4938

De Francesco, G., & **Sullivan, T.** (2023) Improved estimation of P-Delta effects on the response of bilinear SDOF systems. *Earthquake Spectra,* **39(2)**, 889 – 913

de la Torre, C., Bradley, B., Kuncar, F., **Lee, R., Wotherspoon, L.,** & Kaiser, A. (2023) Combining observed linear basin amplification factors with 1D nonlinear site-response analyses to predict site response for strong ground motions: Application to Wellington, New Zealand. *Earthquake Spectra,* **40(1)**, 143 – 173

Delano, J., **Howell, A.,** Clark, K., & **Stahl, T.** (2023) Upper plate faults may contribute to the paleoseismic subsidence record along the central Hikurangi Subduction Zone, Aotearoa New Zealand. *Geochemistry, Geophysics, Geosystems,* **24(10)**, e2023GC011060

Derakhshan, H., **Ingham, J.,** Griffith, M., & Thambiratnam, D. (2023) Simulated seismic testing of two pitched roofs constructed using timber trusses extracted from vintage unreinforced masonry buildings. *Earthquake Engineering and Structural Dynamics,* **52(14)**, 4754 – 4771

Dong, C., De Francesco, G., **Sullivan, T., Dhakal, R.,** Elder, T., Fryer, E., & Velagapudi, N. (2023) Seismic protection of artefacts with adhesives and base-isolation. *Bulletin of the New Zealand Society for Earthquake Engineering,* **56(3)**, 186 – 200

Dong, W., Li, M., **Sullivan, T., MacRae, G., Lee, C.,** & Chang, T. (2023) Direct displacement-based seismic design of Glulam frames with buckling restrained braces. *Journal of Earthquake Engineering,* **27(8)**, 2166 – 2197

Dupuis, M., Schill, C., **Lee, R.**, & **Bradley, B.** (2023) A deep-learning-based model for quality assessment of earthquake-induced ground-motion records. *Earthquake Spectra,* **39(4)**, 2492 – 2517

Filippova, O., Elwood, K., & **Collins, T.** (2023) Challenges in post-earthquake recovery of damaged and neglected buildings in Christchurch CBD. *Bulletin of the New Zealand Society for Earthquake Engineering,* **56(1)**, 38 – 54

Francis, T., Opabola, E., **Sullivan, T., Elwood, K.,** & Belliss, C. (2023) Seismic fragility of reinforced concrete buildings with hollow-core flooring systems. *Bulletin of the New Zealand Society for Earthquake Engineering,* **56(4)**, 250 – 260

Francis, T., **Sullivan, T.,** & Filiatrault, A. (2023) Shake table testing and modeling of New Zealand light-frame wood buildings. *Journal of Structural Engineering (United States),* **149(12)**, 04023165

Gerstenberger, M., Rhoades, D., **Litchfield, N.,** Abbott, E., Goded, T., Christophersen, A., Van Dissen, R., Bannister, S., Barrell, D., Bruce, Z., Fry, B., Hamling, I., Holden, C., **Horspool, N.,** Kaiser, A., Kaneko, Y., **Langridge, R.,** Little, T., Lukovic, B., McBride, S., McVerry, G., Nicol, A., Perrin, N., Pettinga, J., **Stirling, M.,** Van Houtte, C., & Wallace, L. (2023) A time-dependent seismic hazard model following the Kaikōura M7.8 Earthquake. *New Zealand Journal of Geology and Geophysics,* **66(2)**, 192 – 216

Gonzalez, R., **Stephens, M., Toma, C.,** & Dowdell, D. (2023) Incorporating potential environmental impacts in building seismic design decisions. *Bulletin of Earthquake Engineering,* **21(9)**, 4385 – 4428

Grimson, D., **McDonald, G., McDonald, N.,** Monge, J., & **Brown, C.** (2023) Accounting for economy-wide effects, risk aversion, and inequality aversion in the cost-benefit analyses of extreme events. *International Journal of Disaster Risk Reduction,* **102**, 104254

Gu, A., Zhou, Y., Lu, Y., Yang, Q., **Henry, R.,** & **Rodgers, G.** (2023) Planar frame models considering system-level interactions of a two-story low-damage concrete wall building. *Earthquake Engineering and Structural Dynamics,* **52(14)**, 4325 – 4351

Hashemi, A. (2023) Effect of serviceability limit state and over-strength mechanism on seismic performance of self-centring low damage structures with friction connections. *Structures,* **55**, 231 – 244

Hnat, T., **McGann, C.,** & **Wotherspoon, L.** (2023) The state of practice in soil-structure interaction modelling in New Zealand. *Bulletin of the New Zealand Society for Earthquake Engineering,* **56(3)**, 169 – 185

Hoang, T., & **Noy, I.** (2023) The income consequences of a managed retreat. *Regional Science and Urban Economics,* **100**, 103896

Hogan, L., Henry, R., & **Ingham, J.** (2023) Out-of-plane behaviour of dowel type precast panel-to-foundation connections. *Structures,* **58**, 105447

Hopkins, W. (2023) Safe as houses? The limits of seismic building regulation in Aotearoa New Zealand. *New Zealand Law Review,* **23(3)**, 323 – 347

Hopkins, W., Natoli, T., & Avila, L. (2023) As the island choirs gather: Tracing a regional approach to disaster and climate resilience in Pacific island countries. *Yearbook of International Disaster Law,* **4(1)**, 152 – 174

Hudson-Doyle, E., Thompson, J., Hill, S., Williams, M., Paton, D., Harrison, S., Bostrom, A., & **Becker, J.** (2023) Where does scientific uncertainty come from, and from whom? Mapping perspectives of natural hazards science advice. *International Journal of Disaster Risk Reduction,* **96**, 103948

Hulsey, A., Horspool, N., Gerstenberger, M., Sullivan, T., & **Elwood, K.** (2023) Considering uncertainty in the collapse fragility of New Zealand buildings for risk-targeted seismic design. *Earthquake Engineering and Structural Dynamics,* **52(13)**, 4205 – 4221

Jalayer, F., Ebrahimian, H., Trevlopoulos, K., & **Bradley, B.** (2023) Empirical tsunami fragility modelling for hierarchical damage levels. *Natural Hazards and Earth System Sciences,* **23(2)**, 909 – 931

John, L., Williamson, M., & **Sullivan, T.** (2023) Investigating the impact of design criteria on the expected seismic losses of multi-storey office buildings. *Bulletin of the New Zealand Society for Earthquake Engineering,* **56(1)**, 11 – 28

Kerby, C., Monical, J., & **Pujol, S.** (2023) Earthquake response of reinforced concrete frames with infill and active external confinement: Tests and dataset. *Earthquake Spectra,* **40(1)**, 885 – 907

Khattak, N., Derakhshan, H., Thambiratnam, D., Perera, N., & **Ingham, J.** (2023) Using heritage building registers to characterise unreinforced masonry buildings of Brisbane, Australia. *Australian Journal of Structural Engineering,* **24(1)**, 1 – 23

Kluger, M., Lowe, D., Moon, V., Chaneva, J., Johnston, R., Villamor, P., Ilanko, T., Melchert, R., **Orense, R.,** Loame, R., & Ross, N. (2023) Seismically-induced down-sagging structures in tephra layers (tephra-seismites) preserved in lakes since 17.5 cal ka, Hamilton lowlands, New Zealand. *Sedimentary Geology,* **445**, 106327

Kumar Bothara, J., Ahmad, N., **Ingham, J.**, & Dizhur, D. (2023) Mechanical properties of stone masonry set in mud mortar and contained by steel wire mesh. *Construction and Building Materials,* **405**, 133348

Li, L., **Chang-Richards, A., Boston, M., Elwood, K.,** & Hutt, C. (2023) Post-disaster functional recovery of the built environment: A systematic review and directions for future research. *International Journal of Disaster Risk Reduction,* **95**, 103899

Li, Z., **del Rey Castillo, E., Henry, R.,** & Thompson, A. (2023) Axial compression testing of concrete prisms confined by FRP spike anchors and estimation of failure modes. *Composite Structures,* **322**, 117403

Lin, A., & **Wotherspoon, L.** (2023) The use of global versus region-specific data for the prediction of co-seismic landslides. *Engineering Geology,* **327**, 107335

Liu, J., Zhang, R., Yan, Z., Xie, J., Chouery, K., Jia, L., Xiang, P., Zhao, X., **Ramhormozian, S., Dhakal, R., Clifton, G.,** & **MacRae, G.** (2023) Experimental study on low-damage performance of sliding hinge joint. *Soil Dynamics and Earthquake Engineering,* **169**, 107871

Liu, R., Palermo, A., & **Chiaro, G.** (2023) Effect of reinforcing and crack width on the vibration damping capacity of rubberized concrete beams. *Structural Concrete,* **24(2)**, 2740 – 2754

McEwan, E., **Stahl, T., Howell, A., Langridge, R.,** & Wilson, M. (2023) Coseismic river avulsion on surface rupturing faults: Assessing earthquake-induced flood hazard. *Science Advances,* **9(18)**, eadd2932

Miranda, C., **Becker, J., Toma, C.,** & **Vinnell, L.** (2023) Homeowners' perceptions of seismic building performance and implications for preparedness in New Zealand. *Natural Hazards Review,* **24(1)**, 022047

Miranda, C., **Toma, C., Stephens, M.,** & **Becker, J.** (2023) Predictions of damage to timber-framed houses: Aligning social and engineering predictions of earthquake damage before and after strengthening. *Natural Hazards Review,* **24(4)**, 4023038

Miranda, C., **Toma. C.,** & **Stephens, M.** (2023) Predictions of damage to timber-framed houses. I: Seismic performance of wood framed houses located on slopes. *Natural Hazards Review,* **24(4)**, 04023037

Mowll, R., Anderson, M., **Logan, T., Becker, J., Wotherspoon, L., Stewart, C., Johnston, D.,** & Neely, D. (2023) A new mapping tool to visualise critical infrastructure levels of service following a major earthquake. *Progress in Disaster Science,* **21**, 100312

Mowll, R., **Becker, J., Wotherspoon, L., Stewart, C., Johnston, D.**, & Neely, D. (2023) Creating a 'planning emergency levels of service' framework – a silver bullet, or something useful for target practice? *Resilient Cities and Structures,* **2(2)**, 1 – 12

Mowll, R., **Becker, J., Wotherspoon, L., Stewart, C., Johnston, D.,** & Neely, D. (2023) Infrastructure planning emergency levels of service for the Wellington region, Aotearoa New Zealand - An operationalised framework. *Bulletin of the New Zealand Society for Earthquake Engineering,* **56(4)**, 234 – 249

Noy, I., Okubo, T., Strobl, E., & Tveit, T. (2023) The fiscal costs of earthquakes in Japan. *International Tax and Public Finance,* **30(5)**, 1225 – 1250

Orumiyehei, A., & **Sullivan, T.** (2023) Simplified seismic loss assessment using limit state loss-intensity models. *Bulletin of the New Zealand Society for Earthquake Engineering,* **56(3)**, 127 – 151

Pascua, C., **Henry, R.,** & **Toma, C.** (2023) Review of recently constructed concrete wall-steel frame hybrid buildings. *Bulletin of the New Zealand Society for Earthquake Engineering,* **56**, 91 – 103

Pollalis, W., Shah, P., Zhang, Y., Mankame, N., Zavattieri, P., & **Pujol, S.** (2023) Dynamic response of a single-degree-of-freedom system containing phase transforming cellular materials. *Engineering Structures,* **275**, 115205

Rangwani, K., **MacRae, G.,** & **Rodgers, G.** (2023) Performance of rocking frames with friction tension-only devices. *Bulletin of the New Zealand Society for Earthquake Engineering,* **56(2)**, 71 – 90

Rincon, J., Chen, Y., **Pujol, S.,** Puranam, A., & Hwang, S. (2023) Shear strength of RC columns with external post-tensioned clamps. *Structural Journal,* **121(2)**, 111 – 125

Roeslin, S., **Ma, Q.,** Chigullapally, P., Wicker, J., & **Wotherspoon, L.** (2023) Development of a seismic loss prediction model for residential buildings using machine learning - Ōtautahi/Christchurch, New Zealand. *Natural Hazards and Earth System Sciences,* **23(3)**, 1207 – 1226

Safaei, S., **MacRae, G.,** & Moghadam, A. (2023) Column base flexibility effects on the seismic performance of single-bay single-story steel moment frames. *Journal of Earthquake Engineering,* **27(8)**, 2279 – 2297

Sarkis, A., **Sullivan, T.**, Brunesi, E., & Nascimbene, R. (2023) Assessment of the torsional behavior of hollow-core slabs. *Bulletin of the New Zealand Society for Earthquake Engineering,* **56(2)**, 104 – 114

Sarkis, A., **Sullivan, T.,** Brunesi, E., & Nascimbene, R. (2023) Investigating the effect of bending on the seismic performance of hollow-core flooring. *International Journal of Concrete Structures and Materials,* **17(1)**

Shirmohammadli, Y., **Hashemi, A.,** Masoudnia, R., & **Quenneville, P.** (2023) Numerical modeling investigation of cross-laminated timber connections consisting of multiple glued-in rods. *Structures,* **53**, 491 – 500

Shirmohammadli, Y., Pizzi, A., Raftery, G., & **Hashemi, A.** (2023) One-component polyurethane adhesives in timber engineering applications: A review. *International Journal of Adhesion and Adhesives,* **123**, 103358

Shrestha, S., & **Orchiston, C.** (2023) Context, culture, and cordons: The feasibility of post-earthquake cordons learned through a case study in Kathmandu Valley, Nepal. *Earthquake Spectra,* **39(4)**, 2152 – 2172

Shrestha, S., & **Pujol, S.** (2023) Drift capacity of reinforced concrete columns. *ACI Structural Journal,* **120(1)**, 215 – 224

Singeisen, C., **Massey, C.,** Wolter, A., **Stahl, T.,** Kellett, R., Bruce, Z., Bloom, C., & Mason, D. (2023) Evolution of an earthquake-induced landslide complex in the South Island of New Zealand: How fault damage zones and seismicity contribute to slope failures. *Geosphere,* **20(1)**, 267 – 289

Stephens, M., Xu, Z., **Whittaker, C.,** & **Wotherspoon, L.** (2023) Vulnerability of power distribution utility poles to tsunami bore impacts. *Journal of Coastal and Hydraulic Structures,* **3(22)**

Stolte, A., Wotherspoon, L., Cox, B., Wood, C., Jeong, S., & Munro, J. (2023) The influence of multiple impedance contrasts on mHVSR site period estimates in the Canterbury Plains of New Zealand and implications for site classification. *Earthquake Spectra,* **39(1)**, 288 – 309

Stronach, A., & **Stern, T.** (2023) A new basin depth map of the fault-bound Wellington CBD based on residual gravity anomalies. *New Zealand Journal of Geology and Geophysics,* **66(1)**, 27 – 41

Tan, M., Vinnell, L., Valentin, A., **Prasanna, R.,** & **Becker, J.** (2023) The public's perception of an earthquake early warning system: A study on factors influencing continuance intention. *International Journal of Disaster Risk Reduction,* **97**, 104032

Tarbali, K., **Bradley, B.,** & Baker, J. (2023) Effect of near-fault directivity pulses on ground-motion intensity measure correlations from the NGA-West2 data set. *Earthquake Spectra,* **39(4)**, 2263 - 2280

Tomlinson, H., **Rodgers, G.,** Xu, C., Avot, V., Zhou, C., & Chase, J. (2023) Accuracy and robustness of hysteresis loop analysis in the identification and monitoring of plastic stiffness for highly nonlinear pinching structures. *Smart Structures and Systems,* **31(2)**, 101 – 111

Vantassel, J., **Stolte, A., Wotherspoon, L.,** & Cox, B. (2023) AutoHVSR: A machine-learning-supported algorithm for the fully-automated processing of horizontal-to-vertical spectral ratio measurements. *Soil Dynamics and Earthquake Engineering,* **173**, 108153

Vinnell, L., Milfont, T., & **McClure, J.** (2023) Natural hazard versus natural disaster: Does framing the event affect preparedness intentions, attitudes, and behaviour? *Social Psychological Bulletin,* **18**, e8357

Vinnell, L., Tan, M., Prasanna, R., & **Becker, J.** (2023) Knowledge, perceptions, and behavioral responses to earthquake early warning in Aotearoa New Zealand. *Frontiers in Communication,* **8**, 1229247

Walsh, E., **Stahl, T., Howell, A.,** & **Robinson, T.** (2023) Two-dimensional empirical rupture simulation: Examples and applications to seismic hazard for the Kaikoura Region, New Zealand. *Seismological Research Letters,* **94(2A)**, 852 – 870

Wang, G., Jiang, S., Wang, G., & **Ingham, J.** (2023) Numerical investigation of precast concrete frames with grouted sleeves and intermediate connections. *Structures,* **51**, 1474 – 1496

Wang, Y., & **Orense, R.** (2023) Numerical investigation of inclined piles under liquefaction-induced lateral spreading. *Geotechnics,* **3(2)**, 320 – 346

Watson, M., **Brown, C.,** Handmer, J., Kroll, C., Wein, A., Helgeson, J., Rose, A., Dormady, N., & Kim, J. (2023) Methods and lessons for business resilience and recovery surveys. *International Journal of Disaster Risk Reduction,* **93**, 103743

Wilson, T., & **Noy, I.** (2023) Fifty years of peril: A comprehensive comparison of the impact of terrorism and disasters linked to natural hazards (1970–2019). *Global Policy,* **14(5)**, 647 – 662

Yan, Z., **Ramhormozian, S., Clifton, G.,** Zhang, R., Xiang, P., Jia, L., **MacRae, G.,** & Zhao, X. (2023) Numerical studies on the seismic response of a three-storey low-damage steel framed structure incorporating seismic friction connections. *Resilient Cities and Structures,* **2(1)**, 91 – 102

Yang, T., Zuo, X., **Rodgers, G.,** & Bagatini-Cachuço, F. (2023) Mechanism development and experimental validation of self-centering nonlinear friction damper. *Engineering Structures,* **287**, 116093

Yang, X., **del Rey Castillo, E.,** Zou, Y., & **Wotherspoon, L.** (2023) Semantic segmentation of bridge point clouds with a synthetic data augmentation strategy and graph-structured deep metric learning. *Automation in Construction,* **150**, 104838

Zhang, R., Yan, Z., Liu, J., Xie, J., Chouery, K., Xiang, P., Zhao, X., **MacRae, G., Clifton, G., Dhakal, R., Ramhormozian, S.,** & Jia, L. (2023) Seismic performance of a low-damage rocking column base joint along weak axis. *Journal of Building Engineering,* **67**, 106056

Zhou, H., **Wotherspoon, L.,** Hayden, C., **Stolte, A.,** & **McGann, C.** (2023) Applicability of existing CPT-Vs correlations to shallow holocene Christchurch soils based on direct push crosshole testing. *Engineering Geology,* **313**, 106927

Zhu, C., Cotton, F., Kawase, H., & **Bradley, B.** (2023) Separating broad-band site response from single-station seismograms. *Geophysical Journal International,* **234(3)**, 2053 – 2065

Published Conference Proceedings (Direct Peer-Reviewed)

Abeling, S., Miranda, C., & **Becker, J.** (2023) Public expectations of damage and disruption to existing multi-storey buildings in earthquakes. *New Zealand Society for Earthquake Engineering 2023 Annual Conference*

Ahmed, H., Vishnupriya, V., & **Rodgers, G.** (2023) The effectiveness of linear viscous damper and damper subsystem stiffness on response reduction in SDOF system subjected to different ground motions. *Australian Earthquake Engineering Society 2023 National Conference*

Bhanu, V., **Chandramohan, R.**, & **Sullivan, T.** (2023) Method for the explicit consideration of ground motion duration in NZS 1170.5. *New Zealand Society for Earthquake Engineering 2023 Annual Conference*

Chiaro, G., Christian, S., Goldingham, L., & Murali, A. (2023) Direct shear response of gravel-glass-rubber mixtures. *Concrete New Zealand Conference 2023*

Chiaro, G., Tasalloti, A., Palermo, A., & Banasiak, L. (2023) Small-strain shear stiffness and strain-dependent dynamic properties of gravel-rubber mixtures. *17th Symposium on Earthquake Engineering*

de Cristofaro, M., Chiaradonna, A., Damiano, E., Netti, N., Asadi, M., Olivare, L., & **Orense, R.** (2023) Modeling of the accumulation process of the excess pore water pressure for pyroclastic soils. *6th World Landslide Forum*

Deng, T., & **Henry, R.** (2023) Dynamic analysis of tall reinforced concrete walls designed with minimum vertical reinforcement. *New Zealand Society for Earthquake Engineering 2023 Annual Conference*

Dong, C., & **Sullivan, T.** (2023) Investigating the impacts of building importance level and ductile design on the performance of base-isolated buildings in New Zealand. *Canadian Conference - Pacific Conference on Earthquake Engineering 2023*

Dong, C., **Sullivan, T.,** & Pettinga, D. (2023) Base isolated building performance and the impact of the National Seismic Hazard Model. *New Zealand Society for Earthquake Engineering 2023 Annual Conference*

Dupuis, M., Paterson, J., **Lee, R.,** & **Bradley, B.** (2023) Progress towards hybrid broadband ground-motion simulation of megathrust earthquakes on the Hikurangi Subduction Zone. *Canadian Conference - Pacific Conference on Earthquake Engineering 2023*

Gómez-De la Peña, E., Coco, G., **Whittaker, C.,** & Montaño, J. (2023) A deep learning model to predict shoreline change. *Coastal Engineering Conference*

Gu, A., **Rodgers, G.,** & **Henry, R.** (2023) A displacement-based design method for low-damage dual systems with hysteretic and nonlinear viscous energy dissipation. *New Zealand Society for Earthquake Engineering 2023 Annual Conference*

Gu, A., **Rodgers, G., Henry, R.,** Lu, Y., & Zhou, Y. (2023) Simulated responses of a two-story concrete wall building shake-table test. *Canadian Conference - Pacific Conference on Earthquake Engineering 2023*

Haymes, K., **Sullivan, T.,** & **Chandramohan, R.** (2023) A review of practice-oriented methods for estimating seismic demands on parts and components. *New Zealand Society for Earthquake Engineering 2023 Annual Conference*

Hazaveh, N., **Rodgers, G.,** & Chase, J. (2023) Avoiding moat wall pounding of base-isolated buildings using D3 viscous dampers. *New Zealand Society for Earthquake Engineering 2023 Annual Conference*

Hernández, E., Palermo, A., **Chiaro, G.,** & **Scott, A.** (2023) Cyclic shear test of reinforced rubberised concrete columns. *International Symposium of the International Federation for Structural Concrete*

Kerby, C., **Pujol, S.,** & **Henry, R.** (2023) Experimental study of staggered lap splices in RC structural walls. *Concrete New Zealand Conference 2023*

Li, Y., **Chang-Richards, A., Boston, M., Elwood, K.,** & Hutt, C. (2023) Lessons learned from the 2010/2011 Canterbury earthquakes in New Zealand. *Canadian Conference - Pacific Conference on Earthquake Engineering 2023*

Li, Z., **del Rey Castillo, E.,** & **Henry, R.** (2023) Seismic strengthening of RC walls using FRP to prevent axial failure. *New Zealand Society for Earthquake Engineering 2023 Annual Conference*

Moustafa, M., **Henry, R.,** & **Elwood, K.** (2023) Hollow-core floor unit webcracking and retrofit using supplemental shear reinforcement. *Concrete New Zealand Conference 2023*

Muñoz, G., **Henry, R.,** & **Elwood, K.** (2023) Testing of heavily damaged reinforced concrete walls repaired using concrete and steel replacement. *New Zealand Society for Earthquake Engineering 2023 Annual Conference*

Pascua, C., **Henry, R., Toma, C.,** & **Clifton, C.** (2023) Design and testing of concrete wall steel beam connection. *Concrete New Zealand Conference 2023*

Pascua, C., **Henry, R., Toma, C.,** & **Clifton, C.** (2023) Experimental tests on concrete wall-steel beam connections. *International Symposium of the International Federation for Structural Concrete*

Pokhrel, A., & **Chiaro, G.** (2023) Small-strain shear stiffness of sand-gravel mixtures. *8th International Symposium on Deformation Characteristics of Geomaterials*

Ramhormozian, S., Clifton, C., & **MacRae, G.** (2023) Recent and ongoing research, developments, and implementations of friction-sliding seismic resisting systems in New Zealand. *International Symposium of Steel Structures*

Rangwani, K., **Rodgers, G., MacRae, G., Ramhormozian, S., Clifton, G.,** & Yan, Z. (2023) Initial performance and reliability assessment of a frictional GripNGrab device during experimental component testing. *Canadian Conference - Pacific Conference on Earthquake Engineering 2023*

Rincon, J., & **Pujol, S.** (2023) Retrofit and repair of reinforced concrete columns with active confinement. *New Zealand Society for Earthquake Engineering 2023 Annual Conference*

Shaswat, S., & **Orense, R**. (2023) Use of innovative materials as ground improvement technique to mitigate soil liquefaction. *26th Australasian Conference on Mechanics of Structures and Materials*

Stolte, A., Brown, C., Lee, K., Manea, E., & **Wotherspoon, L.** (2023) Estimates of site periods from mHVSR analysis of IRIS temporary seismograph networks. *New Zealand Society for Earthquake Engineering 2023 Annual Conference*

Taheri, H., Karpenko, M., **Clifton, C., Ramhormozian, S.,** Dong, P., **Lim, J.**, & **Roy, K.** (2023) Seismic application of fillet and partial penetration butt welds. *New Zealand Society for Earthquake Engineering 2023 Annual Conference*

Tapuke, K., Kaiser, L., **Johnston, D.,** McCombe, G., & **Becker, J.** (2023) Enhancing earthquake and tsunami preparedness and response in Kura Kaupapa Māori/ schools in Tairāwhiti and Waiāriki, Aotearoa New Zealand. *New Zealand Society for Earthquake Engineering 2023 Annual Conference*

Thorpe-Loversuch, S., Stratford, W., & **Stern, T.** (2023) Shallow shear wave reflection surveys in urban environments. *New Zealand Geoscience Society Annual Conference*

Tiwari, A., **de la Torre, C., Bradley, B., Lee, R.,** & Kuncar, F. (2023) Trends in systematic site residuals with geomorphic categories for New Zealand ground-motion instrument sites. *New Zealand Society for Earthquake Engineering 2023 Annual Conference*

Vinnell, L., Johnston, D., Hogan, L., Stephens, M., & **Horspool, N.** (2023) Meet EDDIE – QuakeCoRE's new earthquake test dummy. *New Zealand Society for Earthquake Engineering 2023 Annual Conference*

Wang, K., Li, M., & **Liu, A.** (2023) Comparison of seismic performance on plasterboard bracing walls and plywood shear walls in the context of New Zealand light timber-framed structures. *Canadian Conference - Pacific Conference on Earthquake Engineering 2023*

Wright, T., Li, M., Moroder, D., & **Carradine, D.** (2023) Design of mixed angle screw CLT hold-down connections to New Zealand standards. *New Zealand Society for Earthquake Engineering 2023 Annual Conference*

Ying, F., Wang, G., & Curtis, M. (2023) Eliminating the building quality issues: A theoretical framework using the theory of planned behaviour. *13th International Conference on Engineering*

Zhan, S., **Chang-Richards, A., Boston, M.,** & **Elwood, K.** (2023) Impeding factors causing delays in the long-term recovery of Christchurch CBD. *Canadian Conference - Pacific Conference on Earthquake Engineering 2023*

QuakeCoRE Annual Meeting Posters

95 posters were presented at the Te Hiranga Rū QuakeCoRE Annual Meeting in Ahuriri Napier from 29 August – 31 August, 2023

Agarwal, S., **Hashemi, A.,** & **Quenneville, P.**
Seismic behaviour factors for rocking cross-laminated timber walls with friction devices

Aigwi, E., Ge, Y., & Nwadike, A.
Assessing the flood vulnerability of New Zealand's earthquake-prone heritage buildings due to climate change patterns

Alger, B., Thomas, K., & Kaiser, L.
Papa Wiri: Te Ao Māori disaster risk reduction through participatory design and co-design of educational tools

Anderson, M., **Logan, T.,** & Brunner, L.
Functional isolation: The compounding burden amidst cascading infrastructure network failures and disrupted supply chains

Andige, N.
How might green and blue infrastructure planning considerations inform the re-design of public open spaces for DRR?

Apriani, I.
Medium Density Housing (MDH) – Preliminary study to develop low-damage solution for low-rise residential building

Assadi, S., **Hashemi, A.,** & **Quenneville, P.**
Upcoming large scale experimental test of a two-storey rocking timber wall structure with innovative low-damage floor connections

Azul, K., **Orense, R.,** & **Wotherspoon, L.**
Assembling liquefaction-related data for the development of hybrid liquefaction prediction model

Bae, S., Ridden, J., Schill, C., Paterson, J., **Bradley, B.,** & **Lee, R.**
Cybershake NZ 2023 updates: New Zealand simulation-based probabilistic seismic hazard analysis

Bora, S., **Bradley, B.,** Manea, E., **Gerstenberger, M., Lee, R.,** Stafford, P., Atkinson, G., Kaiser, A., DiCaprio, C., & Van Dissen, R.
Hazard sensitivities associated with ground-motion characterization modelling for the New Zealand National Seismic Hazard Model Revision 2022

Boston, M., Mayer, B., & **Chang-Richards, A.**
Using tertiary building performance to define post-disaster functionality timeframes for community recovery and resilience

Buck, N., **Hogan, L.,** & **Stephens, M.**
A comparative study of New Zealand and Japanese concrete moment frames designed for low seismic regions

Campbell, A.
Community resilient landscapes: Examining blue green networks as a catalyst for social resilience

Chandrakumar, C., **Prasanna, R.,** Holden, C., **Stephens, M.,** Punchihewa, A., & **Tan, M.**
Extended warning window: A P-wave based community-engaged earthquake early warning system

Chaneva, J., Kluger, M., Moon, V., Lowe, D., & **Orense, R.**
Particle crushing in pumiceous sands and silts during cyclic triaxial loading

Chey, M., Jang, S., & Mehta, V.
Comprehensive seismic damage assessment in Gyeongju City: Integrating local seismic environment with ERGO-EQ platform

Church, C., **Orchiston, C.,** & Saunders, W.
A new direction: Opportunities for national direction on natural hazard management during RMA reform

Clausing, S.
Parenting and family rights in the midst of earthquakes

Collins, T.
Identifying and navigating road cones on the long road to the establishment of the Canterbury Earthquake Insurance Tribunal

Cui, A., **Tan, M.,** & **Prasanna, R.**
CRISiSLab: Advancing resilience through innovative technology for disaster management

Daglish, J., **Stahl, T., Wotherspoon, L., Howell, A.,** & Bloom, C.
Fault displacement hazard in a New Zealand context and implications this has towards the road network exposure.

Daysh, I.
How effective was sluicing as a rockfall remediation method following the 2016 Kaikōura Earthquake?

de la Torre, C., Bradley, B., Lee, R., Tiwari, A., **Wotherspoon, L.,** Ridden, J., & Kaiser, A.
Residual-based non-ergodic site-response adjustments to empirical ground-motion models to account for basin effects in Wellington, New Zealand

Dicaprio, C., Chamberlain, B., Chamberlain, C., & **Gerstenberger, M.**
Exploring the 2022 Aotearoa New Zealand NSHM with Kororā, a public webapp

Evans, R.
More than just a civil defence hub: Ngāi Tahu involvement in the Canterbury earthquake recovery - a model

Fatourehchishabestari, A., **Filippova, O.,** & Rehm, M.
Post-earthquake reconstruction of Christchurch city center- housing challenges

Faulkner, H.
Governing disasters in Aotearoa New Zealand: An Auckland volcanic field case study

Ferner, H., Abeling, S., Beaven, S., **Brown, C.,** Brunsdon, D., Cowan, H., Dunn, C., **Elwood, K.,**Gill, D., Hare, J., & Jury, R.
Resilient Buildings Project: Relating societal expectations to performance objectives for buildings - the earthquake performance outcome framework

Formichetti, G., **Loporcaro, G.,** & Pampanin, S.
Multi-performance parametric framework to enhance the design process and implementation of low-damage timber buildings

Gerstenberger, M., Bora, S., **Bradley, B.,** DiCaprio, C., Kaiser, A., Nicol, A., **Stirling, M.,** Thingbaijam, K., Van Dissen, R. and the NSHM Team
The 2022 Aotearoa New Zealand NSHM

Harvey, J., & **Robinson, T.**
Modelling coseismic landslide impacts on infrastructure systems in Wellington

Holman, B.
Earthquakes, emergency responses targeted at business recovery and gender

Horsfall, S., **Brown, C.,** Kilvington, M., & Horn, C.
Let's talk about risk: Engaging communities in natural hazard and climate change conversations

Inal Kaynar, C., Isaacs, N., Brown, A., & **Noy, I.**
An investigation of the influence of the reuse of heritage buildings on the resilience of New Zealand small town centres

Jaramillo-Velez, A., **Tan, M., Prasanna, R., McColl, S., Stewart, C.,** & de Vilder, S.
Earthquake-triggered rockfalls from coastal cliffs: Can citizen science play a role?

Jeong, S., Kwak, D., & Hwang, E.
Real-time correction of ground motion amplification for a rapid seismic intensity reporting system

Khadka, A., **Costello, S.,** & **Ranjitkar, P.**
A literature review of post-disaster road network performance assessment and management

Kieu, M., & Senanayake, G.
Perception, experience and resilience to risks: A global analysis

Kuncar, F., **Bradley, B., de la Torre, C.,** Rodriguez-Marek, A., Zhu, C., & **Lee, R.**
Frequency-domain methods to account for shallow site effects in hybrid broadband ground-motion simulations

Kuwabara, R., **Hogan, L., Elwood, K.,** & Opabola, E.
Residual capacity of steel reinforcement

Kwon, Y.
CrowdQuake: Earthquake early warning using IoT and deep learning

Lal, R., **Hashemi, A.,** & **Quenneville, P.**
A novel inter-story isolation system for cross-laminated timber (CLT) platform construction- concept development and preliminary evaluation

L'Hermitte, C., Trent, N., & Qin, Y.
Capturing the full complexity of post-disaster freight disruptions in New Zealand: An application of the Theory of Constraints

Li, L., **Chang-Richards, A., Boston, M.,** & **Elwood, K.**
Analysis of quantitative methods for assessing functional recovery post earthquake

Lin, S., Moratalla, J., **Uma, S.,** & Lukovic, B.
Developing and implementing vulnerability functions for multi-storey residential buildings in New Zealand

Liu, Y., **Wang, K.,** Mourot, P., Vorster, C., **Ahn, H.,** Ye, X., **Nair, N.,** & **McDonald, G.**
Enhancing resilience - interdisciplinary machine learning research in QuakeCoRE

Loghman, V., **Bradley, B., Lee, R.,** Schill, C., **Chandramohan, R.,** & **McGann, C.**
Comparison of seismic performance assessment using observed or simulated ground motions in seismic hazard analysis and ground motion selection

Luo, Z., & **MacRae, G.**
Revolutionizing post-earthquake inspections and repairs: The efficacy and cost-effectiveness of using Structural Access Panels (SAPs) in buildings

Mabin, S.
Rockfall risk and lifelines mitigation performance following the 2016 Kaikōura Earthquake

Magill, C., & Hales, S.
Respiratory health impacts of natural hazard events in Aotearoa

Mason, D., Brabhaharan, P., & **Fenton, C.**
Lessons from the 2016 Kaikōura Earthquake for the resilience of earthworks

McDonald, N.
Mitigating FMCG transport bottlenecks following an extended Cook Strait ferry outage in New Zealand

McEwan, E., **Stahl, T., Howell, A., Langridge, R.,** & Wilson, M.
Examining coseismic river response to surface-rupturing fault displacement

Miranda, C., **Brown, C., Becker, J.,** & **Hudson-Doyle, E.**
Seismic risk communication with commercial building tenants

Mostafa, M., **Henry, R.,** & **Elwood, K.**
Seismic performance of precast prestressed hollow-core floors and residual capacity of web-cracked floor units

Mowll, R., **Becker, J., Wotherspoon, L., Stewart, C.,** & **Johnston, D.**
Infrastructure planning emergency levels of service for the Wellington region

Nkrumah, S., **Filippova, O.,** & **Ying, F.**
User-focused post-earthquake functional recovery of commercial buildings in New Zealand

O'Kane, A.
What controls earthquake-induced building damage and what implications do they have for magnitude estimates of historical earthquakes?

Pascua, C., **Henry, R., Toma, C.,** & **Clifton, C.**
Seismic performance of recently-constructed concrete wall-steel frame hybrid buildings

Penney, C., Howell, A., McLennan, T., Nicol, A., & Fry, B.
Investigating the occurrence of Kaikōura-like ruptures in a multi-fault, multi-cycle earthquake simulator

Prasanna, R., Adikari, K., Holden, C., Punchihewa, A., **Stephens, M.,** Drummond, P., Ravishan, D., & Chandrakumar, C.
Feasibility of LPWAN (Low Power Wide Area Network) based communication solutions for Earthquake Early Warning (EEW) and building/infrastructure monitoring systems

Prattley, L., Beaven, S., **Wilson, T.,** Williams, J., & Leonard, G.
Tsunami evacuation behaviour: A review of survey findings across Aotearoa New Zealand

Price, L.
A web application to map disaster impacts from social media posts

Rahayani, R., & **Nair, N.**
AHP analysis for disaster hazard mapping to optimize solar and wind farm site selection

Ramhormozian, S., Yan, Z., **Clifton, C., Quenneville, P., MacRae, G., Dhakal, R.,** Xiang, P., & Jia, L.
Three-storey configurable steel framed building incorporating friction based energy dissipaters

Ravishan, D., **Prasanna, R.,** & **Hudson-Doyle, E.**
Unleashing the potential: AI at the edge of distributed EEW network

Rincon Gil, J., & **Pujol, S.**
Repair of RC concrete columns with post-tensioned clamps

Roundill, M.
The role of housing in tertiary students' ability to prepare for earthquakes

Rowe, C.
Preparing for impact: How is science communication helping us prepare for the next Alpine Fault rupture?

Salimian, M., **del Rey Castillo, E., Hogan, L.,** & **Stephens, M.**
Experimental study on FRP ties used in precast diaphragm strengthening subjected to incompatible support beam rotation and parallel beam elongation

Sarwary, S.
Institutional structures, social capital and community disaster resilience: Can legislative and governance arrangements facilitate community influence on disaster recovery decision making?

Saunders, W.
A national risk tolerance assessment methodology

Scadden, M.
Understanding cascading climate change risks for Māori communities

Scheele, F., **Wilson, T., Becker, J., Horspool, N.,** & Campbell, M.
Simulating household impacts for an Alpine Fault earthquake

Schill, C., **Bradley, B.,** & **Dempsey, D.**
Post-event ground motion estimation using physics-based simulations

Shariati, A., **L'Hermitte, C.,** & **Trent, N.**
Prepositioning of relief items: A study of the factors influencing emergency management decisions

Siddiqui, U.
Enhancing city resilience: A local council's approach in managing risk from earthquake-prone buildings

Stahel, K.
QuakeBox similes: Change and persistence in similes in post-earthquake narratives

Stucki, E., **Trent, N.,** & **L'Hermitte, C.**
Exploring logistics behaviour in Aotearoa New Zealand for better disaster impact modelling using vehicle telemetry data

Syed, Y., & **Uma, S.**
Using decision support system as an infrastructure network planning and visualisation tool for natural hazard risk assessment

Tan, M., Vinnell, L., Valentin, A., **Prasanna, R.,** & **Becker, J.**
Understanding technology adoption of an earthquake early warning system through a continuance intention model

Tapuke, K., Kaiser, L., **Johnston, D., Becker, J.,** & McCombe, G.
Enhancing earthquake and tsunami preparedness and response in kura kaupapa māori/schools in Te Tairāwhiti and Waiāriki, Aotearoa New Zealand

Till, H., **Stephens, M.,** & **Toma, C.**
Tsunami loading on buildings

Tiwari, A., **de la Torre, C., Bradley, B.,** & **Lee, R.**
Investigating systematic site effects and within-site variability in New Zealand: A comprehensive residual analysis of empirical- and physics-based GMMs

Uma, S., & Moratalla, J.
A framework to estimate damage and potential blockages for road network under cascading hazards with propagation of uncertainties

Vercoe, H., **Fa`aui, T.,** & **Wotherspoon, L.**
Adaptation of marae infrastructure for natural hazards resilience

Vincent, K., Crawford-Flett, K., & **Wotherspoon, L.**
Identifying internal instability type with soil microstructure

Wallace, T.
Understanding operational vulnerabilities & systemic risk in integrated stopbank-dam catchments

Wang, Q., & **Henry, R.**
Effect of dynamic loading rates on the seismic response of lightly reinforced concrete walls

Wight, J.
Improving urban food supply chain resilience using DES of local supply chains

Ye, X.
Hierarchical federated learning with social context clustering-based participant selection for resilient internet of things applications

Yu, T., & **del Rey Castillo, E.**
Seismic strengthening of floor diaphragms with carbon fibre materials (CFRP) — FEM modelling

Zhang, J., & **del Rey Castillo, E.**
Optimizing the design of EB-FRP for tension strengthening: Exploring the impact of diverse FRP sheets and anchor configurations

Zhu, C., **Bradley, B.,** & Bora, S.
Spectral decomposition of ground motions in New Zealand using the generalized inversion technique

Zou, Y., **Nair, N.,** & **McDonald, G.**
Intelligent and data-driven infrastructure inspection and management