2019 Annual Report

Te Hiranga Rū | QuakeCoRE

Aotearoa New Zealand Centre for Earthquake Resilience

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Directors' Report 2019

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

In our fourth Annual Report we highlight several world-class research stories, collaborations with national and international partners, and education of the next-generation of New Zealanders.

QuakeCoRE researchers are chasing the 'next frontier' in earthquake resilience to reduce damage to structures through innovative solutions for foundation systems, and the non-structural components that comprise a large portion of the value of buildings. The use of scrap vehicle tyres as an innovative foundation material for seismic resilience is an example of taking present-day environmental problems and turning them into resilience solutions. Similarly, researchers have developed world-first experimental techniques for laboratory testing and seismic qualification of resilient non-structural elements – glazing, partitions, electrical and mechanical equipment – that have historically been ignored, but are essential to achieve functional buildings after earthquakes. Because of inherited vulnerabilities in existing infrastructure, risk transfer through insurance is a common alternative to significant upfront costs to directly undertake mitigation. Such earthquake insurance is not without its detriments, both in an absolute sense, and also in terms of the equality for nationalised schemes. QuakeCoRE research, highlighted in this report, on these attributes of New Zealand's earthquake insurance landscape has also made significant contributions to public debate on these issues associated with the Earthquake Commission Act.

QuakeCoRE continues to exhibit collaborative leadership domestically and internationally. We highlight the strong alignment achieved with the 'Resilience to Nature's Challenges' National Science Challenge, progress associated with our on-going commitment to Mātauranga Māori, partnership research between the public and private sectors through community participation in seismic sensor deployment, and also the 'Learning from Earthquakes' programme as an example of international opportunities to study New Zealand as a natural earthquake laboratory.

Finally, we highlight the educational experiences afforded by QuakeCoRE to our student researcher community, and also the establishment of the National Hazard Public Education Alliance as a means to coordinate science communication across related areas with local stakeholders and iwi.

As we move into 2020, QuakeCoRE looks forward to another productive year, delivering on our vision for the future of earthquake resilience.

Brendon Bradley – Director

David Johnston – Deputy Director

Ken Elwood – Research Director

Chair's Report 2019

Te Hiranga Rū QuakeCoRE continues to provide leadership in research and solutions that help our communities respond and recover, as rapidly as possible, to earthquakes. In fact, everything we do is focussed on building community and infrastructure resilience through innovative research.

For 2019 QuakeCoRE continues as the pre-eminent earthquake research centre in Aotearoa New Zealand. Congratulations to the research community and the leadership of QuakeCoRE for their ongoing commitment and contribution.

Some of the highlights from 2019 include:

- Innovative solutions for foundation systems using scrap vehicle tyres to create resilient building foundations.
- Novel laboratory testing of non-structural elements of buildings such as glazing and electrical equipment, allowing a better understanding of barriers to returning a building to full functionality following a seismic event.
- Support for emerging researchers on community-based risk assessment in Wharekauri The Chatham Islands, supporting local communities to become more resilient after a natural disaster.
- Collaboration with the US-based Earthquake Engineering Research Institute (EERI) on a study tour of New Zealand allowing students and young professionals from around the world to learn first-hand about earthquake recovery.

QuakeCoRE remains committed to collaborating across projects, institutions and research programmes. It is our firm belief that this leads to better outcomes for New Zealand. This underpinning value is shared with our partners – globally and in New Zealand – whether research institutions, industry, iwi or the wider community. We thank them all for their support and contributions.

Thank you to the QuakeCoRE team: Brendon Bradley (Director), David Johnson (Deputy Director) and Ken Elwood (Research Director). The leadership and culture across the programme enables us to focus on research excellence, future development and progress. And indeed, I am grateful to the wider QuakeCoRE Leadership Team and research community for their passion and the difference you are making for New Zealand.

Thank you to the Board for their wisdom, guidance and leadership. Over 2019 our board consisted of Bryony James (University of Auckland) and Mike Mendonça (Wellington City Council), John Hare (Holmes Group), Sir Mark Solomon (Ngāi Tahu), Mary Comerio (University of California, Berkeley, USA), Jan Evans-Freeman (University of Canterbury), and John Reid (University of Canterbury Ngāi Tahu Research Centre).

On behalf of the Board, we are looking forward to 2020.

Dean Kimpton - 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 and has seven 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 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 Outcomes

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 New Zealand infrastructure, rapid business recovery after future earthquakes and the growth of engineering resilience innovation and business in the 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 outreach.

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

Research overview

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 technology platforms, flagship programmes, integrative projects and special projects.

Technology Platforms

- 1: Large-scale Laboratory Testing
- 2: Field Testing & Monitoring
- 3: Multi-Disciplinary Community Databases
- 4: Computational Simulation & Visualisation

Flagship Programmes

- 1: Ground Motion Simulation
- 2: Liquefaction Impacts
- 3: Earthquake-vulnerable Buildings
- 4: Next-generation infrastructure
- 5: Pathways to improve Resilience

Special Projects

- 1: Spatially-distributed Infrastructure

Integrative Projects

- 1: Alpine Fault Earthquake Case Study
- 2: Wellington Earthquake Resilience Collaboratory

Four technology platforms provide the underpinning experimental (lab and field), computational, and data infrastructure that are necessary to support our research programmes and realise QuakeCoRE's vision and mission. Our high-impact research is delivered via five flagship programmes, one integrative project and one special project. These programmes are advancing our research efforts to the next level through multi-institutional and multi-disciplinary research collaboration, engagement with end-users, and co-funding.

Our research programmes are supported by QuakeCoRE contestable and non-contestable funding and have strong links to end-users. Each of the flagship programmes has a named industry representative to facilitate communication at all levels between researchers and end-users.

Technology Platforms

TP1

Large-scale laboratory facilities
Leader: Rick Henry | Deputy Leader: Alessandro Palermo
This Platform supports enhanced collaboration across domestic and international large-scale experimental facilities, innovative testing procedures, and instrumentation.

TP2

Field- testing and monitoring
Leader: Liam Wotherspoon | Deputy Leaders: Quincy Ma & Geoff Rodgers
This Platform is building on Aotearoa New Zealand leadership in field testing and monitoring to focus on development of world-class testing technologies and urban system monitoring.

TP3

Multi-disciplinary community databases
Leader: Ilan Noy | Supported By: TP3 Working Advisory Group
This Platform fosters the contribution to, and utilisation of, existing community databases, as well as enabling the development of new multi-disciplinary databases for transformative research.

TP4

Computational simulation and visualisation
Leader: Brendon Bradley | Deputy Leader: Christopher McGann
This Platform provides computational workflows to connect the multi-disciplinary research activities within Te Hiranga Rū QuakeCoRE and to provide a pipeline by which research results can be understood in terms of their wider impacts on earthquake resilience.

Flagship Programmes

FP1

Ground motion simulation and validation
Leader: Brendon Bradley | Deputy Leaders: David Dempsey & Seokho Jeong
Industry Representative: Didier Pettinga
This Flagship aims to provide a paradigm shift in ground motion prediction via theoretical developments in physics-based simulation methods and their utilisation in engineering design and assessment.

FP2

Liquefaction impacts on land and infrastructure
Leader: Misko Cubrinovski | Deputy Leaders: Rolando Orense & Sjoerd van Ballegooy
Industry Representative: Sjoerd van Ballegooy
This Flagship focuses on next-generation assessment methods and mitigation strategies for soil liquefaction, one of the principal earthquake hazards affecting land and infrastructure in Aotearoa New Zealand.

FP3

Addressing earthquake-vulnerable buildings – A multi-disciplinary approach
Leader: Ken Elwood | Deputy Leader: Ilan Noy | Industry Representative: Derek Baxter
This Flagship addresses the risk posed by collapse-vulnerable earthquake-prone buildings through a multi-disciplinary lens.

FP4

Next-generation infrastructure: Low-damage and repairable solutions
Leader: Tim Sullivan | Deputy Leader: Rick Henry | Industry Representative: Jared Keen
This Flagship seeks a new design paradigm where reparability and damage control is explicitly considered in the design process of buildings and infrastructure.

FP5

Pathways to improved resilience
Leader: David Johnston | Deputy Leaders: Caroline Orchiston & Wendy Saunders
Industry Representative: Dan Neely
This Flagship focuses on determining how we decide where to invest our limited resources to most effectively improve Aotearoa New Zealand's resilience to earthquakes.

Other Projects

Integrative Projects

Earthquake Case study: Alpine Fault Earthquake Impacts
Leader: Brendon Bradley | Deputy Leader Tom Wilson
This case study focused around an Alpine Fault earthquake rupture scenario in order to contextualise each aspect of the earthquake resilience 'pipeline', the expertise for which resides within the Flagships themselves. This project, aligned to the "Project AF8" programme funded by the National Resilience Fund, seeks to apply the latest research understanding for impacts of Alpine Fault earthquakes, and through end-user engagement, use the results of this project toward tangible improvements in Aotearoa New Zealand earthquake resilience. Notably, this case-study project will learn from the Kaikōura Earthquake to better understand the impacts of future Alpine Fault Earthquakes.

Earthquake Case study: Wellington Earthquake Resilience Collaboratory
Leader: Ken Elwood
The Wellington Earthquake Resilience Collaboratory Project was started in 2019 and uses the dynamic natural environment and proactive earthquake-risk mitigation activities in Wellington City and region to provide a unique setting for cross-disciplinary research. Bringing researchers together to consider the key challenges facing Wellington city and region in a major earthquake provides a unique environment in which to understand the different facets of earthquake resilience.

Special Projects

Spatially–distributed Infrastructure
Leader: Liam Wotherspoon | Deputy Leader & Industry Representative: Roger Fairclough
This Special Project is a joint research initiative with the National Science Challenge 10: Resilience to Nature's Challenges. The programme is developing tools to assess the performance of spatially-distributed infrastructure networks subject to extreme natural hazards. This Special Project is a joint research initiative with the National Science Challenge 10: Resilience to Nature's Challenges. The programme is developing tools to assess the performance of spatially-distributed infrastructure networks subject to extreme natural hazards.

Scrap tyres find new lives as earthquake protection

Each year, New Zealanders produce more than five million waste tyres, with 75 per cent of these tyres coming from passenger vehicles. Approximately 30 per cent of them are exported or recycled, but the rest go to landfill, are stockpiled, or illegally dumped.

Wherever they end up, tyres cause substantial environmental and health problems, occupying a large portion of land and potentially harbouring disease-carrying pests, mosquitos and other insects. They can leach metals and chemicals, contaminating soil and water, and can cause large fires that emit toxic gases and are difficult to extinguish.

Te Hiranga Rū QuakeCoRE Associate Investigator, Gabriele Chiaro and his colleagues Alessandro Paterno and Laura Banasiak have found one solution that doubles as a novel form of earthquake protection: using shredded tyres as seismic isolation foundations for medium-density low-rise residential buildings.

The eco-rubber seismic-isolation foundation systems project began in October 2018 with the idea to shred old tyres and mix them with gravelly soils and concrete to create foundation systems made of a geo-technical seismic isolation layer able to dissipate energy and a flexible, rubberised concrete raft foundation able to accommodate settlements. During an earthquake, the rubber absorbs some of the energy coming through seismic waves and allows the gravel particles to move during shaking, working as seismic isolation. The novelty of the project has led to it also attracting MBIE Smart Ideas funding.

“People think the building has to move to absorb the earthquake shaking, but in this case the soil particles also move to help dissipate energy,” he says.

Gabriele says small-scale shake table tests have already proven the concept, and he hopes that it can be tested on a real-scale building in the field in the next few years. “It will not only prevent damage to buildings but diminish the loss to house contents as well.”

The method is similar to base isolation, which is already used successfully for tall buildings, bridges and other critical infrastructure around the world. But Gabriele says the beauty of this project is that it costs much less than traditional base isolators, with the additional benefit of using up materials that would otherwise pollute the environment. The method is ideal for residential buildings, for which normal base isolators would be far too expensive.

“Tyres are not a problem that is going to diminish,” he says. “But they are the source of amazing materials that are available all the time and can be used in many applications.”

Gabriele Chiaro (University of Canterbury)

How effective is insurance for earthquake risk mitigation?

In the first year after the devastating Christchurch Earthquake Sequence, a survey showed the biggest drivers of stress for residents were the continued aftershocks and the loss of people and property.

But in the following years, negotiating with insurance companies was consistently the greatest stress inducer – and that remained the case for seven consecutive years.

Clearly, insurance after a disaster plays a big role in personal psychological recovery, as well as residential homes, business and public infrastructure.

Te Hiranga Rū QuakeCoRE Associate Investigator Ilan Noy says "If you ask people in Christchurch today what is the most important organisation for you in the five years after the earthquakes, the answer is their insurer: what they did, if they paid, how much they paid, and if they fixed the house."

His research has studied the fairness of the public natural hazard insurance system (The Earthquake Commission - EQC) in post-quake Aotearoa New Zealand and found that it was strongly regressive: simply put, the owner of a $3 million house and the owner of a $250,000 house will pay the same annual levy but receive very uneven benefits when it comes to EQC payouts.

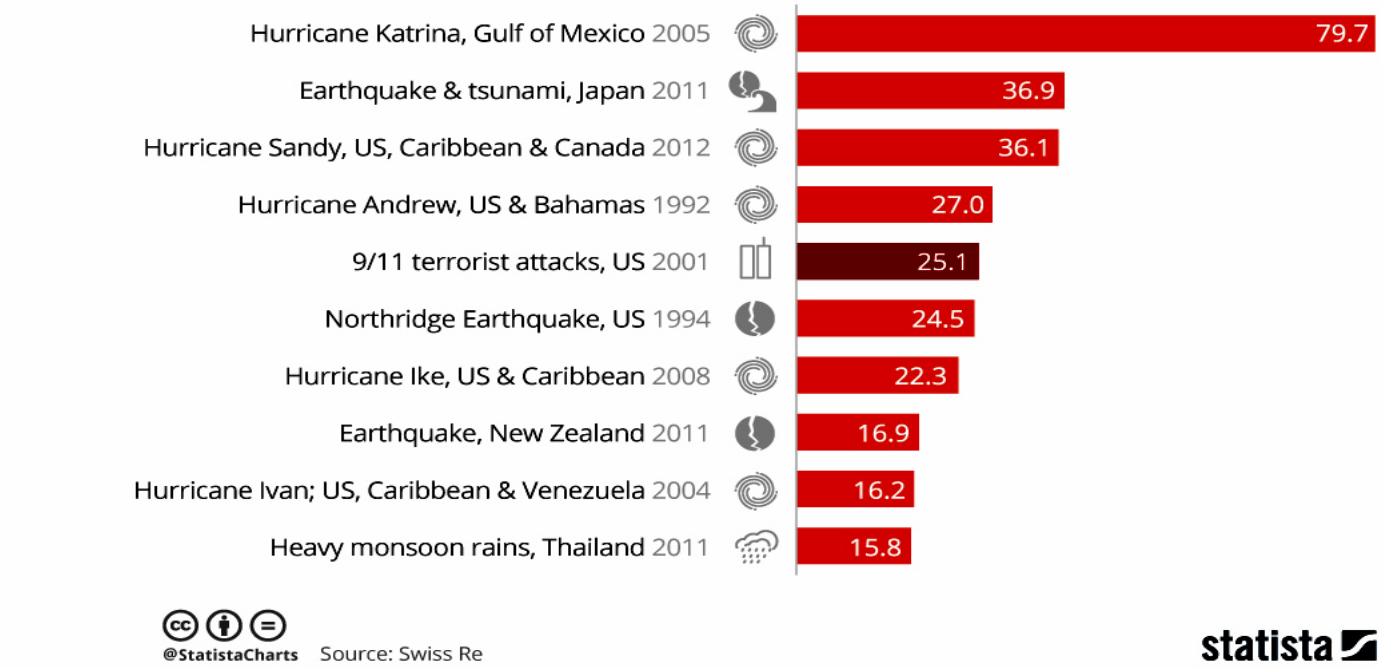
His work has also examined whether insurance payments actually help generate recovery after a disaster. To help ascertain this, the teams studied night-time light intensity in Christchurch – essentially, how many lights were on, an indicator of economic activity – combined with EQC data on payouts, right down to the neighbourhood level of granularity.

The short answer is yes; insurance did help enable recovery, and researchers also found that cash settlement of claims was no more effective than insurance-managed repairs in generating local recovery.

"But there is a caveat: insurance payments took a while to materialise and there were a lot of delays in terms of compensating people for the damages," he says. His paper suggests there is an important role for regulators in ensuring insurance payments are made quickly. "To this day, we still have some open claims nine years later."

The increasing focus of insurers leads to risk-adjustments in premiums, notably increasing private earthquake insurance policies in locations like Wellington. This means Aotearoa New Zealand also needs to consider its current significant reliance on insurance as a mechanism of risk transfer, and what vulnerabilities will emerge if the level of insurance cover continues to materially decrease.

Insurance industry's most costly worldwide catastrophes 1970 – 2015 (in billion US $)



Toward functional buildings following major earthquakes

After an earthquake, immediate attention is mostly focused on ensuring the structural elements in buildings are safe, such as foundations, floors, beams and columns. But insidious damage can happen all over a building and have long-term effects on its functionality and safety.

Non-structural elements such as brick chimneys, facades, internal partition walls, elevators, ceilings, electrical and mechanical equipment and plumbing are crucial to a building's functionality after an earthquake, and weaknesses in those components can contribute to its failure to ensure continued occupancy. For example, windows could be rendered non-weathertight, causing long-term maintenance issues, or a building's fire safety jeopardised because of damage to partition walls.

As part of Te Hiranga Rū QuakeCoRE's Flagship 4 Coordinated Project, Tim Sullivan and Rajesh Dhakal are working on a project that tests the seismic performance of non-structural components of buildings, which both account for the majority of the total investment in a typical building and are the most seismically vulnerable. They aim to help develop improved designs, standards, and technologies as a result.

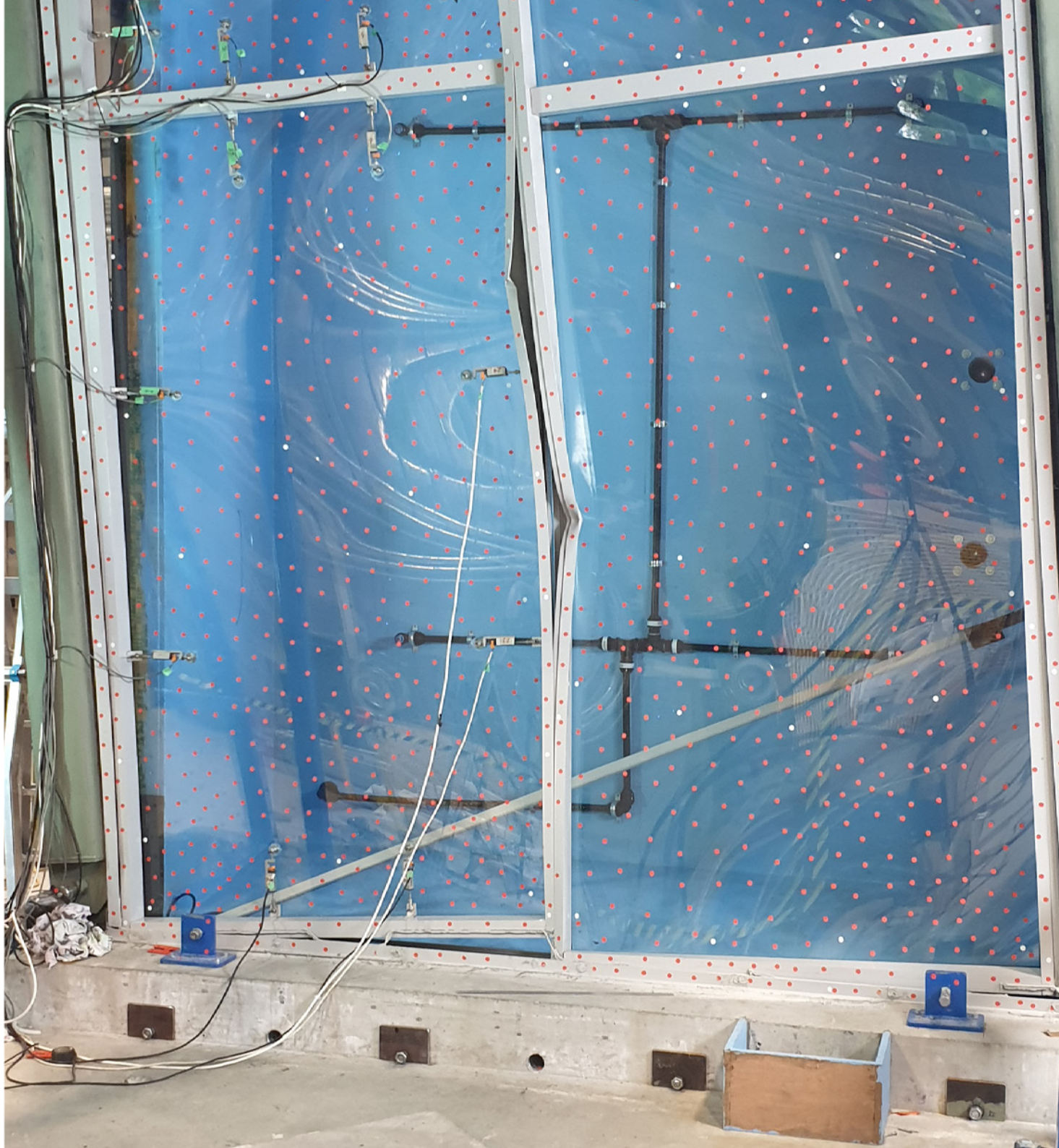
Damage to structures such as these has been extensive during recent earthquakes and can have a significant economic impact. For example, damage sustained to non-structural elements during the 2010-2011 Canterbury Earthquake Sequence contributed heavily to downtime and overall financial loss, Rajesh says.

"However, in the last few years, Aotearoa New Zealand researchers have made important developments in understanding and improving the seismic performance of secondary building elements such as partitions, facades, ceilings and contents." Reducing the damage to these elements can have a significant impact on reducing losses and disruption from earthquakes. During small to medium-sized earthquakes, damage to non-structural elements occurs more often than it does to structural elements – and those small to medium earthquakes are much more frequent than large ones.

But damage can be mitigated through design. For example, ceilings can be better protected by making them fully floating and surrounded by isolation foam, and plasterboard walls can be surrounded by fireproof, deformable, acoustic joints.

While more study is needed, research has already developed better design and technologies. Tim considers the practical elimination of non-structural damage "the next frontier" of earthquake engineering research and implementation.

"Damage to architectural, mechanical or electrical components can lower the performance of the whole building system," Tim says. "Non-structural damage can also lead to limited functionality of critical facilities, such as hospitals, after major seismic events."



Non-structural elements testing (Tim Sullivan)

Collaboration to Impact

Preparing for quakes: Seismic sensors and early warning systems

Earthquakes have always been unexpected and unsettling, but a growing range of prediction methods may make it a little easier for us to prepare for them in future.

Hamish Avery is chief technology officer at Canterbury Seismic Instruments, which develops and deploys low-cost sensors in very high density in Aotearoa New Zealand's urban areas. With Te Hiranga Rū QuakeCoRE 's support, he is working on a project examining how ground motion interacts with particular buildings, something that has been difficult to determine until now.

The sensors' data can be extrapolated into predicting how other buildings of a similar type and shape may behave in an earthquake, indicating which should be evacuated, which may need further investigation, and which are likely to be safe.

"We went through the Christchurch earthquakes and we saw that there was a pattern of no pattern," Hamish says. "You go along and see severe damage to three or four buildings and then no damage to a couple, and then back into damage. There was massive variation in the shaking that went into these buildings."

There are currently a host of sensors in Christchurch, and some in other parts of New Zealand. Hamish hopes that with the support of local councils, New Zealand will one day be covered with them, and to then take the technology international.

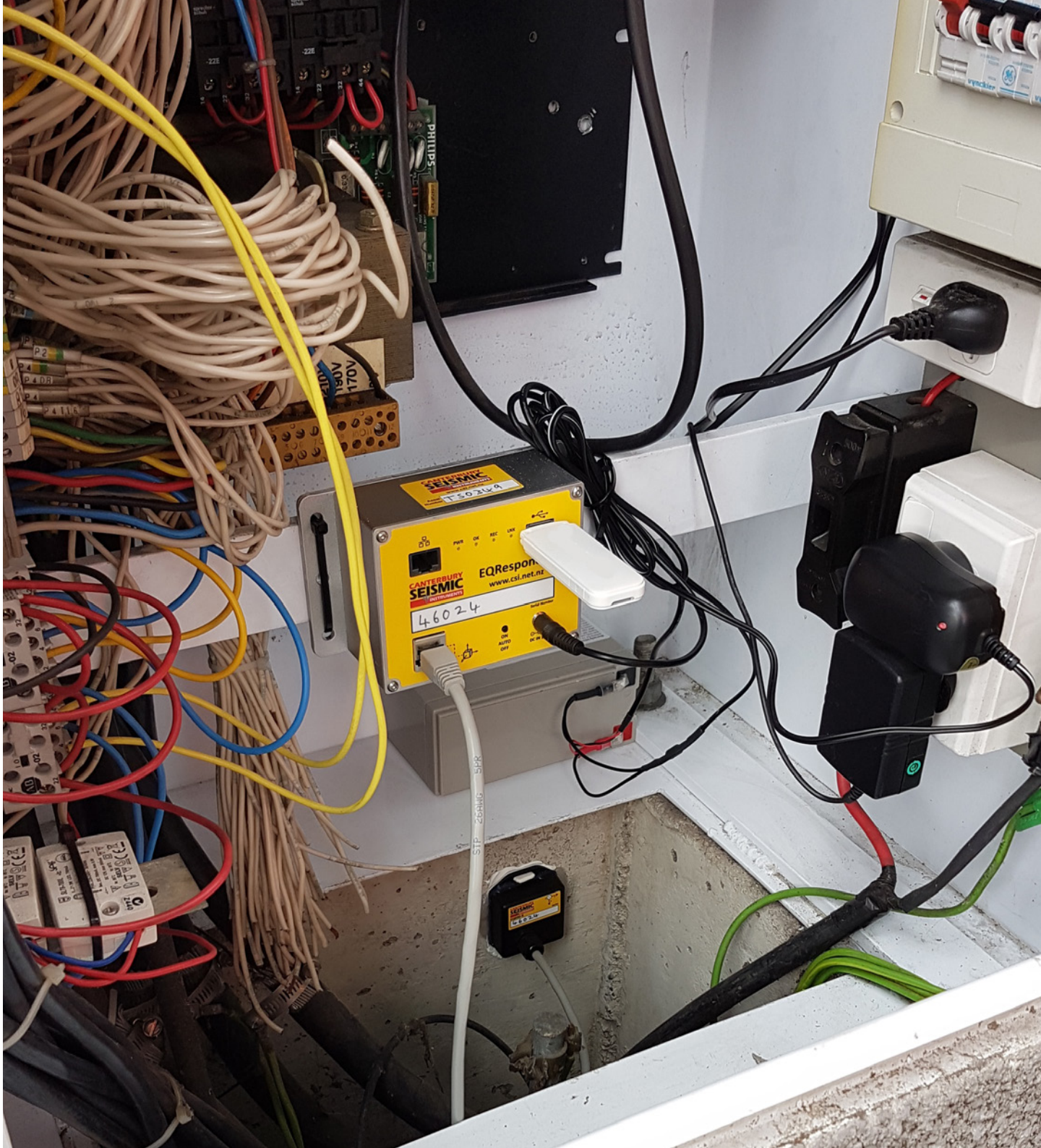
Closely connected to this work is that of Te Hiranga Rū QuakeCoRE's Flagship 3 research, where Ken Elwood is developing a building inventory and models for Wellington to allow a truly digital twin representation of the city, allowing rapid decision-making following earthquakes.

Another project investigating earthquake preparedness examines the societal benefits of early-warning systems which detect seismic waves and send out notifications of an impending quake and asks if it would be beneficial for New Zealand to have one.

QuakeCoRE researcher Julia Becker says that although many countries have developed early-warning technology, few have actually spoken to the general public beforehand.

"They set it up and then talk to people; we are doing it the other way round," she says. "We are talking to people and to the sectors who might be able to use it to find out how they would; for example, shutting down functions and stopping trains.

"It's quite useful to think about how people are going to accept it or use it before you start rolling this stuff out."



Seismic sensor installation (Hamish Avery)

What makes a resilient community?

How resilient is Aotearoa New Zealand to natural hazards? That's the problem being tackled in the second phase of the Resilience to Nature's Challenges National Science Challenge project (RNC2), which began in July 2019.

Of the 20 science leaders in the interdisciplinary programme, nine Te Hiranga Rū QuakeCoRE investigators are at the helm of their individual research themes, ensuring that our earthquake expertise helps improve resilience to other hazards.

Two of those are Liam Wotherspoon, co-leading the Built Environment theme with Tim Sullivan, and Tom Wilson, co-leading the Rural theme with Caroline Orchiston.

The Built Environment theme of the Challenge includes not just buildings, but infrastructure networks such as roads, rail, water, and power, and how they interact.

"Our work programme builds upon some of the work that has been carried out in QuakeCoRE and then expands that scope, while at the same time broadening beyond just earthquakes so it's across a wider range of natural hazards," he says.

The work that the team will do is closely partnered with industry, and will improve our understanding of the performance, resistance and repairability of buildings and infrastructure networks following natural hazard events. It will also develop new tools and processes, and perform state-of-the-art impact modelling to estimate the direct and indirect engineering and economic consequences of natural hazards. This will all help inform future design codes and guidelines.

Out of the city, the resilience of New Zealand's rural landscapes and communities after a natural disaster are also under study. Tom Wilson says major disruption in rural areas can come from a combination of long-term and sudden forces.

After the Kaikōura earthquake, for example, a lack of access to transport networks and other rural value chain disruptions complicated the physical impacts in the land. Drought and the ***M. bovis*** outbreak also played their part.

"Many farms were dealing with multiple stressors in quite a complex risk-scape," Tom says. "We are interested in how best to deal with those slow- and rapid-onset hazards."

Rural New Zealanders are also facing complications from climate change and shifting governmental, social, and economic priorities.

"These communities are facing considerable changes and have already experienced shocks both from the natural environment, the biological environment, and then in the regulatory and political environment," Tom says. "So, what is a resilient rural community? It's a very complex thing."

Otira viaduct (Ruth Hartshorn)

Collaboration a key tool in natural hazard public education

Though most New Zealanders are aware of the need to be better prepared for a natural hazard event, that awareness doesn't always translate into action. For example, if there was a significant earthquake on the Alpine Fault, some communities may need to be self-sufficient for months – and the wider impacts would likely be felt for years.

This means people need to be able to look after themselves, giving forethought to how to obtain and prepare adequate food, water, shelter, sanitary and medical needs, care for pets, and the needs of family members who may need additional support after a natural disaster.

"Most New Zealanders think others will save them, such as Civil Defence or Red Cross," Te Hiranga Rū QuakeCoRE Outreach Coordinator Brandy Alger says. "In major natural hazard events, that will not happen."

Brandy is part of the Natural Hazard Public Education Alliance, which brings together the public education activities of East Coast Life At the Boundary, AF8 [Alpine Fault magnitude 8], QuakeCoRE and Quake Centre. The programmes aim to increase New Zealanders' awareness of natural hazards and their impacts and to enable them to be better prepared.

The Alliance works together to ensure natural hazard risk is talked about in the same way. This collaborative approach enables innovation and the development of shared resources. They meet on a quarterly basis and received funding from EQC in 2019 to support their joint initiatives.

In 2019, Brandy developed an earthquake toolkit to teach children about structural engineering and earthquake resilience. At AF8, Alice Lake-Hammond ran a roadshow, out of which has emerged a Risk Communication toolkit to support ongoing natural hazard public education, and a follow-up roadshow planned for 2020: The Science Beneath Our Feet.

East Coast Life At the Boundary's Kate Boersen says the work they do is all about connection. "Bringing people together makes natural hazard and impact science information easy to access and exciting to learn about."

"New Zealand is such a small country that you don't want to create competition," Brandy says. "Working together, the communication is broader and we are working towards one goal: greater resilience."

QuakeCraft at the Women in Engineering Summer Camp (Clare Burgess)

Human Capability Development

Connections through quakes: International researchers tour New Zealand

From Christchurch to Kaikōura to Wellington, New Zealand's recent significant earthquakes and our subsequent recovery makes for an interesting story to tell the world.

In May 2019, Te Hiranga Rū QuakeCoRE partnered with the US-based Earthquake Engineering Research Institute (EERI) to host a week-long study tour of Aotearoa New Zealand to allow students and young professionals from around the world to learn about earthquake recovery.

For the 24 international and nine New Zealand participants, it was an opportunity to learn from past events, and the programme put together by QuakeCoRE Associate Investigator, Caroline Orchiston and her team was a diverse tour of New Zealand's earthquake landscapes, closely linked to the groups' learning themes of response, recovery and resilience.

New Zealand was the perfect place to host the tour, Caroline says. "because we have this beautiful land of living examples to look at."

Beginning with three days in Christchurch, the group then visited Kaikōura and Wellington, listening to speakers and undertaking different activities before giving group presentations at the end based on their observations.

"They had this incredible experience of seeing two post-quake disaster zones and the possibility of a third in the future," Caroline says. "That's right across the

spectrum of a post-disaster city, the recent response, and the fear of something happening in Wellington."

One highlight was stopping at the 'Wall of Waiau' in Hurunui, a three-and-a-half-metre wall formed when the earthquake struck in November 2016. There the group also used state-of-the-art equipment to 3D scan earthquake-induced deformation and the large Leader River landslide dam that formed after the 2016 Kaikōura Earthquake, when six million cubic metres of material created Lake Rebekah.

The group also examined Kaikōura in terms of post-earthquake recovery, looking at response and resilience in relation to their sub-themes of the built environment, society, community, business and schools.

Caroline says the trip has strengthened relationships with EERI, which is sponsoring her to visit in May 2020.

"Working with their team was fantastic, and I think for the students it was really valuable because they become part of an international network," she says. The group involved people from places as diverse as the United States, Japan, Singapore, Chile, Peru, China and more.

"They met people from all over the world. Many stayed friends, and some went off and travelled together afterward. Through chatting to people from around the world about some of the challenges they're facing elsewhere, they figure out that we're all in this together."

Study tour group, Turanga Library (Paul Daly)

Research in Te Ao Māori

In the past few years, Te Hiranga Rū QuakeCoRE has been developing its mātauranga Māori research and understanding. In June 2019, we organised a hui at Nelson's Whakatū marae to wānanga on earthquake resilience with Māori disaster and resilience researchers from across Aotearoa to discuss areas of mutual interest and concern and to map out a future path that better incorporates Māoritanga.

David Johnston, director of the Joint Centre for Disaster Research at Massey's School of Psychology, says that as a Pākehā at the hui representing QuakeCoRE leadership, it was "a seminal moment of understanding the meaning of partnership in the truest sense". The experience was built into Te Hiranga Rū QuakeCoRE 's new rebid, along with a mātauranga Māori strand.

QuakeCoRE is also supporting several mātauranga Māori research projects. One is a spinoff of Hawke's Bay book Te Hīkoi a Rūaumoko/Rūaumoko's Walk, a bilingual pukapuka (picture book) designed for local kohanga reo-aged tamariki. Emily Campbell (Ngati Porou, Te Aitanga a Mate), a Research Officer at the Joint Centre for Disaster Research, is project manager of the effort to turn the pukapuka into an online, screen-based interactive version.

"The project adheres to tikanga as it is operating in a Te Ao Māori space, and that was non-negotiable from the outset," she says. "We meet kanohi-ki-te-kanohi (face-to-face), make decisions by consensus, have input from kaumatua, and above all, privilege Te Reo Māori and then build the English translation around that."

"Using the voices of the local community is an important part of creating resources that look and feel like the people they're talking to. And it also engages key parts of the community in the decision-making, because they're more informed."

For her UC Masters research, Kristie-Lee Thomas (Ngāti Mutunga o Wharekauri) worked with people from her home of Wharekauri-Rēkohu Chatham Islands. They undertook a community-based risk assessment to inform disaster risk reduction initiatives.

"We continued the mahi with the support of QuakeCoRE to communicate these cocreated results in culturally grounded ways," she says.

"There is a push nationally and internationally to include Mātauranga Māori in disaster risk reduction, recognising that we have knowledge and experience going back 800+ years from living here and throughout Polynesia."

"It's recognising that our knowledge and tikanga around hazards, our dynamic environment and our people have a vital role to play in disaster risk reduction, and how we implement strategies driven by Māori, with Māori, and which work for Māori and our wider communities."

Kristee-lee Thomas (Lucy Kaiser)

The QuakeCoRE postgraduate experience

Shakti Shrestha was in Nepal during the devastating earthquake of 2014, which killed 9,000 people and injured nearly 220,000 more. An architect at the time, his volunteer relief work post-quake sparked an interest in changing his career to something that would have a greater humanitarian impact. He turned to urban planning, with a focus in disaster management, and now researches the impacts of cordons put in place after emergencies, an area of limited research worldwide.

Shakti, a PhD student at the University of Otago's Centre for Sustainability, is one of many supported by Te Hiranga Rū QuakeCoRE through scholarships, direct, and indirect funding. The postgraduate experience is unique, offering unparalleled connections across many different disciplines and organisations.

There are three student-led QuakeCoRE Emerging Research Chapters (QERC) in Auckland, Christchurch and Wellington, which are run for the students by the students with support from academic mentors and the QuakeCoRE Outreach Coordinator Brandy Alger.

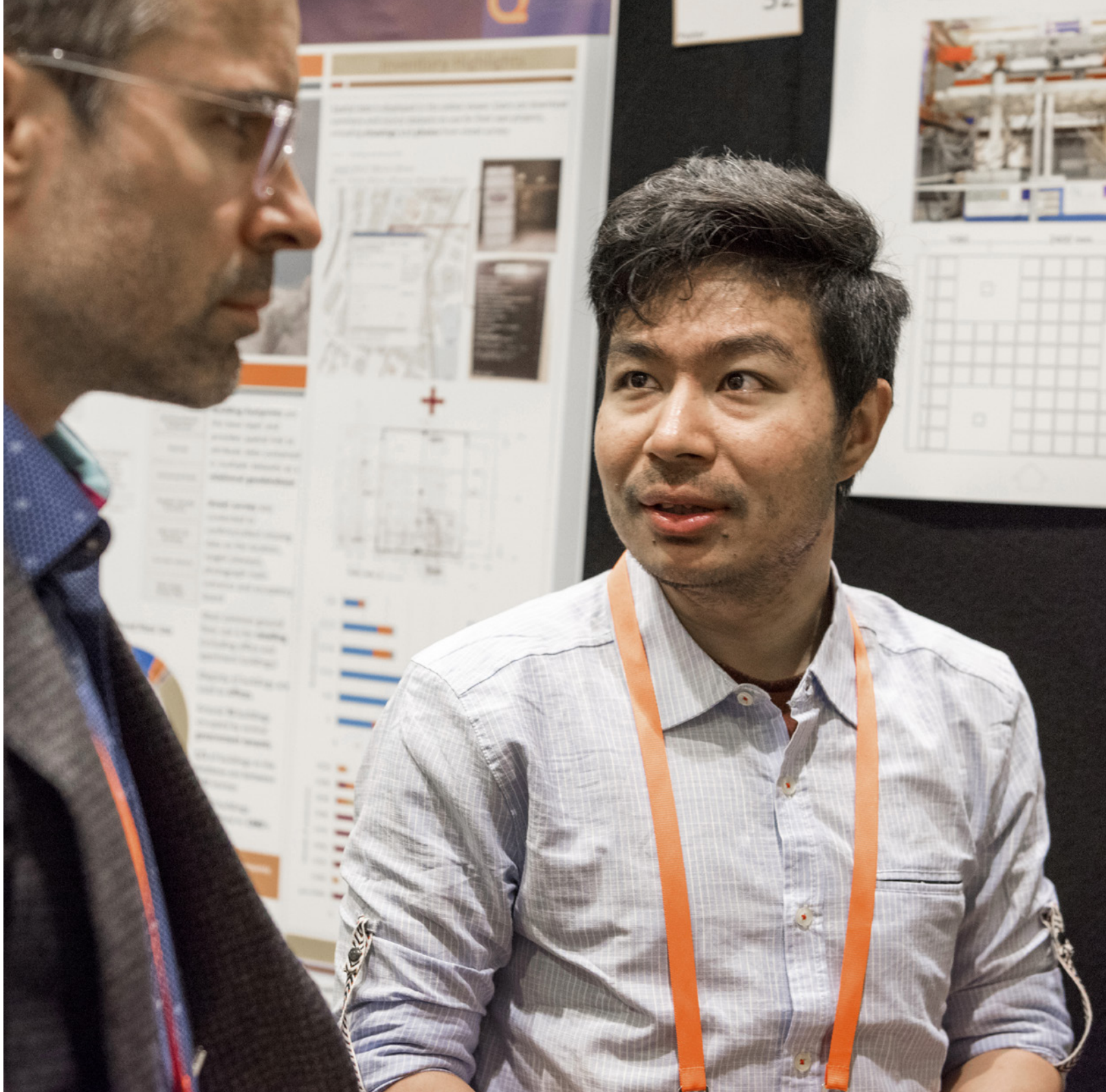
"I think the post-graduate experience has been very wonderful," Shakti says. "I think the best thing I have found about QuakeCoRE which I haven't seen anywhere else is linking up with different themes of study: legal people doing research, technical and social science aspects, and then all of this is presented to and done in collaboration with the people who are actually going to do something about it: the council. A lot of times, academia is in a bubble."

University of Canterbury PhD student Sarah Neill is the chair of the QuakeCoRE Emerging Researcher chapter in Canterbury, while studying the uncertainties associated with predicting ground shaking and how to increase its accuracy.

"We facilitate networking, skills-building workshops, visiting researcher seminars; things like that which are targeted at people doing their PhDs and young researchers," she says. "It creates a community, particularly for those people that might be from other countries, so it's a good way to meet people and form a network."

Eyitayo Opabola is a QuakeCoRE scholar in the Civil and Environmental Engineering Department at the University of Auckland, researching the seismic behaviour and assessment of reinforced concrete structures. His work has contributed to the recently updated New Zealand seismic assessment guidelines for such structures.

"QuakeCoRE is like a big community," he says. "After conducting research in two countries before coming to New Zealand, QuakeCoRE has been the best for me in terms of providing a very good multidisciplinary environment to facilitate good research."



Shakti Shrestha (Steve Hussey)

Recognition highlights

Misko Cubrinovski, University of Canterbury

In January 2019, Misko Cubrinovski was awarded the American Society of Civil Engineers (ASCE) Ralph B. Peck Award for outstanding contributions to the geotechnical engineering profession through the publication of several insightful field case histories. Only the second recipient outside of North America to receive the award in its 21-year history, the award recognised Misko's contributions to the understanding of the triggering and consequences of liquefaction.

Beth Gross, American Society of Civil Engineers and Misko Cubrinovski (ASCE)

Joint Centre for Disaster Research, Massey University

The Joint Centre for Disaster Research team, was awarded the Massey University Research Medal – Team for 2019.

The medal recognises the centre as “a multi-disciplinary team with an outstanding national and international reputation” and for its “commitment of all team members to research excellence that connects with the wider society.”

The team includes QuakeCoRE Investigators David Johnston, Christine Kenney, Suzanne Phibbs, Raj Prasanna, Emma Hudson-Doyle, Denise Blake, Julia Becker and Research Officers Lucy Kaiser, Emily Lambie and Emily Campbell.

JCDR Team (J Stewart)

Geoff Rodgers, University of Canterbury

In November 2019, Geoff Rodgers and Geoff Chase, were awarded the University of Canterbury's highest recognition for an outstanding innovator; The Innovation Medal Tohu Pākai Auaha. The medal is awarded by the University Council for excellence in transforming academic knowledge or ideas that are adopted by the wider community in ways that contribute beneficial value.

The award recognises their research into earthquake mitigation devices, including the design of a low-cost suite of energy dissipation and seismic damping devices. Already these devices have enabled major changes in how structures are designed and built to create economically resilient cities and communities following an earthquake.

Geoff Rodgers (University of Canterbury)

Concrete New Zealand Learned Society Recognitions

In 2019, the New Zealand Concrete Society recognised Te Hiranga Rū QuakeCoRE researchers for the following contributions:

- The QuakeCoRE-ILEE Low-Damage Concrete Building Test was awarded a commendation for their full-scale shake table tests of a low-damage concrete building. The award recognised the collaboration between QuakeCoRE researchers Yiqiu Lu, Rick Henry, Ken Elwood and Geoff Rodgers and their counterparts at Tongji University in China, a QuakeCoRE Affiliate Organisation.
- The Sandy Cormack Best Paper Award was awarded to Lewis Bradford Consulting Engineers for their paper on Hybrid Rocking Precast Concrete Wall Panels used at Christchurch's Turanga Library a project that involved QuakeCoRE Investigators Brendon Bradley and Geoff Rodgers.
- QuakeCoRE Investigators Lu, Henry, Rodgers, Elwood also received a commendation for their paper on the QuakeCoRE ILEE collaboration.
- QuakeCoRE Scholar Mayank Tripathi received the student concrete prize.

New Zealand Society for Earthquake Engineering Recognitions

In 2019, Te Hiranga Rū QuakeCoRE researchers were acknowledged by the New Zealand Society for Earthquake Engineering (NZSEE) with various awards and recognitions:

- Jason Ingham was awarded best research paper for his paper with Nona Taute and Tumanako Fa'aui entitled "Rūaumoko: More than just a symbol".
- Virginie Lacross from Tonkin + Taylor won the inaugural QuakeCoRE / NZSEE Women in Earthquake Engineering Award recognising the contribution of a younger academic or professional woman for ingenuity and entrepreneurial spirit in the field of earthquake engineering.
- The Seismic Resilience Award for Design to Achieve Low Damage was conferred on Lewis Bradford Consulting Engineers for Turanga (Christchurch Library), QuakeCoRE Investigators Brendon Bradley and Geoff Rodgers were involved in the project.
- QuakeCoRE Scholars Eyitayo Opabola and Alex Shegay won the research scholarship and best student paper awards respectively.
- Board Member John Hare from Holmes Consulting was awarded Best Practice Paper.
- David Johnston was elected as a Fellow of NZSEE for his services to earthquake engineering in New Zealand.

Other Recognitions

- Ilan Noy was awarded the Distinguished Research Award from the International Society for Integrated Disaster Risk Management Distinguished Research Award Ilan Noy.
- Caroline Orchiston and Project AF8 were recognised by the Emergency Media and Public Affairs with the Excellence in Resilience and Readiness Award for the AF8 Roadshow.

Financials, Community & Outputs

Financials

Category	Total ($000s)
CoRE Funding	4,163
Total Revenue	**4,163**
Directors and Principal Investigators	227
Associate Investigators	0
Postdoctoral Fellows	162
Technology Platform Staff & Research Technicians	463
Others	260
Total Salaries & Salary–related Costs	**1,112**
Overheads	955
Project Costs	649
Travel	166
Postgraduate Students	690
Equipment Depreciation/Rental	0
Subcontractors(s)	220
Total Other Costs	**2,680**
Less: Host and Partner Support	114
Total Expenditure	**3,678**
Net Surplus/(Deficit)	**485**

2019 At a glance

Category	Detailed category	FTE	2019
People	Principal Investigators	2.10	8
	Associate Investigators	0.10	51
	Postdoctoral Fellows	2.14	8
	Technology Platform Staff/ Research Technicians	6.79	18
	Administration/Support	4.00	6
	Research Students	98.50	117
	Total	**113.63**	**208**
Peer-reviews research outputs	Journal Articles		72
	Conference Papers		43
	Total		**115**
Value of external research contracts awarded	Vote Science and Innovation Contestable Funds		$4,990,496
	Other NZ Government		$441,680
	Domestic – Private Sector Funding		$54,676
	Overseas		$193,462
	Domestic – Other Non-government Funding		$27,000
	Total		**$5,707,314**
Students studying at CoRE	Doctoral Degree		95
	Other		22
	Total		**117**
Number of students completing qualifications	Doctoral Degree		11
	Other		7
	Total		**18**
Immediate post-study graduate destinations	Further study in NZ		1
	Further study Overseas		0
	Employed in NZ		10
	Employed Overseas		5
	Unknown		2
	Total		**18**
Commercial activities	Invention disclosures		1
	Patents granted		1

Community

59
Investigators

30
Industry Affiliates

17
Affiliate Organisations

Board

Dean Kimpton (Chair)	Auckland City Council
Mary Comerio	University of California, Berkeley
Jan Evans-Freeman	University of Canterbury
John Hare	Holmes Consulting Group
Bryony James	University of Auckland
Mike Mendonça	Wellington City Council
John Reid	Ngāi Tahu Research Centre
Tā Mark Solomon	

International Science Advisory Panel

Mary Comerio (Chair)	University of California, Berkeley
Jack Baker	Stanford University
Tom O'Rourke	Cornell University
Ellen Rathje	University of Texas at Austin

Leadership Team

Brendon Bradley (Director)	University of Canterbury
David Johnston (Deputy Director)	Massey University
Ken Elwood (Research Director)	University of Auckland
Misko Cubrinovski	University of Canterbury
Caroline Orchiston	University of Otago
Wendy Saunders	GNS Science
Tim Sullivan	University of Canterbury
Liam Wotherspoon	University of Auckland

Principal Investigators

Ken Elwood	University of Auckland
Brendon Bradley	University of Canterbury
Misko Cubrinovski	University of Canterbury
Jason Ingham	University of Auckland
David Johnston	Massey University
Erica Seville	Resilient Organisations
Tim Sullivan	University of Canterbury
Liam Wotherspoon	University of Auckland

Associate Investigators

Julia Becker	Massey University
Ann Brower	University of Canterbury
Deidre Brown	University of Auckland
Reagan Chandramohan	University of Canterbury
Alice Chang-Richards	University of Auckland
Gabriele Chiaro	University of Canterbury
Charles Clifton	University of Auckland
Toni Collins	University of Canterbury
David Dempsey	University of Auckland
Rajesh Dhakal	University of Canterbury
Dmytro Dizhur	University of Auckland
Olga Filippova	University of Auckland
Sonia Giovinazzi	University of Canterbury
Connor Hayden	University of Auckland
Richard Henry	University of Auckland
Lucas Hogan	University of Auckland
John Hopkins	University of Canterbury
Nick Horspool	GNS Science
Emma Hudson-Doyle	Massey University
Matthew Hughes	University of Canterbury
Seokho Jeong	Waikato University
Christine Kenney	Massey University
Minghao Li	University of Canterbury
Quincy Ma	University of Auckland
Gregory MacRae	University of Canterbury
Chris Massey	GNS Science
John McClure	Victoria University of Wellington
Christopher McGann	University of Canterbury
Mark Milke	University of Canterbury
Hugh Morris	University of Auckland
Nirmal Nair	University of Auckland
Katharina Naswall	University of Canterbury
Ilan Noy	Victoria University of Wellington
Caroline Orchiston	University of Otago
Rolando Orense	University of Auckland
Alessandro Palermo	University of Canterbury
Michael Pender	University of Auckland
Suzanne Phibbs	Massey University
Raj Prasanna	Massey University
Geoffrey Rodgers	University of Canterbury
Vinod Sadashiva	GNS Science
Wendy Saunders	GNS Science
Allan Scott	University of Canterbury
Mark Stirling	University of Otago
Mark Stringer	University of Canterbury
Bridgette Sullivan-Taylor	University of Auckland
SR Uma	GNS Science
Chris Van Houtte	GNS Science
Bernard Walker	University of Canterbury
Colin Whittaker	University of Auckland
Thomas Wilson	University of Canterbury

Industry Affiliates

Richard Apperley	Aurecon
Jawad Arefi	Beca
Sarah Bastin	Beca
Jeff Bayless	AECOM
Nicholas Brooke	Compusoft Engineering
Dave Brunsdon	Kestrel Group
Des Bull	Holmes Consulting
Nigel Colenso	ABI Piers
Patrick Cummuskey	Auckland Council
James Dismuke	Golder Associates
Michael Drayton	Risk Management Solutions
Roger Fairclough	Neo Leaf Global
Jeff Fraser	Golder Associates
Reza Jafarzadeh	Auckland Council
Weng Yuen Kam	Beca
Jared Keen	Beca
Angela Liu	BRANZ
Alan McMahon	Colliers International
Rebecca McMahon	Beca
Gareth Morris	Holmes Consulting
Dan Neely	WREMO
Matt Ogden	Tonkin + Taylor
Aasha Pancha	Aurecon
Didier Pettinga	Holmes Consulting
Dario Pietra	Holmes Consulting
Aimee Rhodes	Opus International Consultants
Andreas Skarlatoudis	AECOM
Paul Somerville	AECOM
Richard Voss	Warren and Mahoney Architects
Rick Wentz	Wentz Pacific

Postdoctoral Fellows

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

Yiqui Lu	University of Auckland
Max Stephens	University of Auckland
Daniel Blake	University of Canterbury
Giovanni De Francesco	University of Canterbury
Maxim Millen	University of Canterbury
Trung Dung Nguyen	University of Canterbury
Karim Tambali	University of Canterbury
Jagdish Vyas	University of Canterbury

Students

In addition to the students listed below that received direct support towards their postgraduate studies, there are a significant number of additional aligned students that are funded with external funding.

Prestige Scholarship Recipients

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

Shannon Abeling	University of Auckland
Xavier Bellagamba	University of Canterbury
Claudio Cappellaro	University of Canterbury
Pavan Chigullapally	University of Auckland
Chris de la Torre	University of Canterbury
Riwaj Dhakal	University of Canterbury
Tom Francis	University of Canterbury
Francisco Gálvez Gonzalez	University of Auckland

Martín García Cartagena	Massey University
Henrieta Hamilton Skurak	University of Canterbury
Rabia Ijaz	University of Canterbury
Anna Kowal	University of Otago
Vahid Loghman	University of Canterbury
James Maguire	University of Auckland
Nikolaos Ntritsos	University of Canterbury
Eyitayo Opabola	University of Auckland
Ana Sarkis Fernandez	University of Canterbury
Mehdi Sarrafzadeh	University of Auckland
Alex Shegay	University of Auckland
Mayank Tripathi	University of Canterbury

Students

In addition to the students listed below, that received direct support towards their postgraduate studies, there are a significant number of additional aligned students that are funded with external funding.

Mohammad Aghababaei	University of Auckland
Itohan Aigwi	Massey University
Fransiscus Asisi Arifin	University of Canterbury
Mohammad Bagher Asadi	University of Auckland
Ananth Balachandra	University of Auckland
Tyler Barton	University of Canterbury
Vishvendra Bhanu	University of Canterbury
Muhammed Bolomope	University of Auckland
Matthew Brenin	Massey University
Ann Brown	University of Canterbury
Nancy Brown	Massey University
Frank Bueker	University of Auckland
Ellenna Caudwell	University of Waikato
Ashley Cave	University of Waikato
Danny Chan	University of Auckland
Jackson Chen Yu	University of Auckland
Mathew Darling	University of Canterbury
Gary Djojo	University of Auckland
Wenchen Dong	University of Canterbury
Mike Dupuis	University of Canterbury
Holly Faulkner	University of Canterbury
Davide Forcellini	University of Auckland
Kevin Foster	University of Canterbury
Francisco Galvez	University of Auckland
Srijana Gurung Shrestha	University of Canterbury
Siwon Han	University of Auckland
Yujia Han	University of Auckland
Mahdi Hatami	University of Canterbury
Kieran Haymes	University of Canterbury
Rangika Hewa Algiriyage	Massey University
Thoa Hoang	Victoria University Wellington
Saanchi Kaushal	University of Auckland
Nardia Kearns	Massey University
Duncan Maina	University of Auckland
Damon McKibbin	University of Canterbury
Catalina Miranda	University of Auckland
Gonzalo Muñoz Arriagada	University of Auckland
Sunil Nataraj	University of Auckland
Sarah Neill	University of Canterbury
Hewa Algiriyage Nilani	Massey University
Amirhossein Orumiyehei	University of Canterbury
Jae Park	University of Canterbury
Michael Parr	University of Canterbury
Marie Claire Pascua	University of Auckland
Bruce Pepperell	Massey University
Anastasiia Plotnikova	University of Auckland
Zaid Rana	University of Auckland
Kiran Rangwani	University of Canterbury
Ebad Rehman	University of Auckland

Hayden Rickard	Victoria University Wellington
Shakti Shrestha	University of Otago
Tomomi Suzuki	University of Auckland
Marion Tan	Massey University
Ethan Thomson	University of Canterbury
Lauren Vinnell	Victoria University Wellington
Amanda Wallis	Victoria University Wellington
Clare Wilkinson	University of Canterbury
Natacha Wisstt	University of Canterbury
Robin Xie	University of Canterbury
Zhonghou Xu	University of Auckland
Qun Yang	University of Auckland
Kenny Yee	University of Auckland
Majid Zakerinia	University of Auckland

Other Staff

Technology Platform Staff

In addition to the Technology Platform staff listed below, there are a number of additional related roles that are supported with aligned funding

Sung Bae	IT Architect, TP4
Yiqui Lu	TP1
Sally Owen	TP3
Andrew Stolte	Field Research Engineer, TP2

Support Staff

Ruth Hartshorn	Operations Manager
Brandy Alger	Outreach Coordinator
Amy McGeddie	Administrator
Rosemary Walton	Research Coordinator

Affiliate Organisations

Building Research Institute (BRI)	Tsukuba , Japan
Copenhagen Centre for Disaster Research (COPE)	Copenhagen, Denmark
DesignSafe	Austin, USA
EPICentre	London, UK
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
Liquefact	Chelmsford, UK
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
Quake Centre	Christchurch, New Zealand
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

Partners

University of Canterbury (Host)
BRANZ
GNS Science
Massey University
Resilient Organisations
University of Auckland
University of Waikato
Victoria University of Wellington

Publications

115 Peer-reviewed Outputs

95 Annual Meeting Posters

Journal Publications (Direct Peer-Reviewed)

Calvert, R., **Whittaker, C.**, Raby, A., Taylor, P., Borthwick, A., & van den Bremer, T. (2019). Laboratory study of the wave-induced mean flow and set-down in unidirectional surface gravity wave packets on finite water depth. *Physical Review Fluids*, **4(11)**, 114801

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Amies, A., Pretty, C., **Rodgers, G.**, & Chase, J. (2019). Experimental validation of a radar-based structural health monitoring system. *IEEE/ASME Transactions on Mechatronics*, **24(5)**, 2064-2072

Asadi, M., **Orense, R.**, Asadi, M., & **Pender, M.** (2019). Maximum dry density test to quantify pumice content in natural soils. *Soils and Foundations*, **59(2)**, 532-543

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Bradley, B. (2019). On-going challenges in physics-based ground motion prediction and insights from the 2010–2011 Canterbury and 2016 Kaikōura, New Zealand earthquakes. *Soil Dynamics and Earthquake Engineering*, **124**, 354-364

Brooke, N., **Elwood, K.**, Bull, D., Liu, A., **Henry, R.**, **Sullivan, T.**, **Hogan, L.**, & del Rey Castillo, E. (2019). ReCast Floors - Seismic assessment and improvement of existing precast concrete floors. *SESOC Journal*, **32**, 50-59

Brown, C., **Seville, E.**, Hatton, T., Stevenson, J., Smith, N., & Vargo, J. (2019). Accounting for business adaptations in economic disruption models. *Journal of Infrastructure Systems*, **25(1)**,

Brown, N., Rovins, J., Feldmann-Jensen, S., **Orchiston, C.**, & **Johnston, D.** (2019). Measuring disaster resilience within the hotel sector: An exploratory survey of Wellington & and Hawke's Bay, New Zealand hotel staff and managers. *International Journal of Disaster Risk Reduction*, **33**, 108-121

Brown, N. , Campbell, E., **Johnston, D.**, McCracken, H., Bradley, S., Dray, S., & Neely, D. (2019). Wellington Resilience workshop: Creating shared ideas and meanings. *Australasian Journal of Disaster and Trauma Studies*, **23(2)**, 101-111

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Bruneau, M., & **MacRae, G.** (2019). Building structural systems in Christchurch's post-earthquake reconstruction. *Earthquake Spectra*, **35(4)**, 1953-1978

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Clement, C., Abeling, S., Deely, J., Teng, A., Thomson, G., **Johnston, D.**, & Wilson, N. (2019). Descriptive epidemiology of New Zealand's highest mortality earthquake: Hawke's Bay in 1931. *Scientific Reports*, **9(1)**, 4914

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Dizhur, D., Giaretton, M., Giongo, I., Walsh, K., & **Ingham, J.** (2019). Material property testing for the refurbishment of a historic URM building in Yangon, Myanmar. *Journal of Building Engineering*, **26**, 100858

Fikri, R., **Dizhur, D.**, & **Ingham, J.** (2019). Typological study and statistical assessment of parameters influencing earthquake vulnerability of commercial RCFMI buildings in New Zealand. *Bulletin of Earthquake Engineering*, **17(4)**, 2011-2036

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Orumiyehei, A., & **Sullivan, T.** (2019) Improving the accuracy of the SAC/FEMA approach. *7th ECCOMAS Thematic Conference on Computational Methods in Structural Dynamics and Earthquake Engineering, COMPDYN 2019.*

Pettinga, D., Sarrafzadeh, M., & **Elwood, K.** (2019) The serviceability of resilient design in New Zealand. *Pacific Conference on Earthquake Engineering.*

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Stringer, M., Asadi, M., **Orense, R.**, Asadi, M. & **Pender, M.** (2019) Cyclic behavior of undisturbed samples from pumice-rich soils. *7th International Conference on Earthquake Geotechnical Engineering.*

Tan, M., **Prasanna, R.**, Stock, K., **Hudson-Doyle, E.**, Leonard, G., & **Johnston, D.** (2019) Enhancing the usability of a disaster app: Exploring the perspectives of the public as users. *16th ISCRAM Conference.*

Tarbali, K., **Bradley, B.**, Huang, J., Lee, R., Lagrava, D., Bae, S., Polak, V., Motha, J., & Zhu., M. (2019) Cybershake NZ V18.5: New Zealand simulation-based probabilistic hazard analysis. *Pacific Conference on Earthquake Engineering.*

Yost, K., Cox, B., **Wotherspoon, L.**, Boulanger, R., Van Ballegoy, S., & **Cubrinovski, M.** (2019) In-situ investigation of false-positive liquefaction sites in Christchurch, New Zealand: Palinurus Road case history. *GeoCongress 2019: Geotechnical Special Publication.*

QuakeCoRE Annual Meeting Posters

95 posters were resented at the QuakeCoRE Annual Meeting in Whakatū Nelson from 3 – 5 September, 2019.

Abeling, S., **Ingham, J.**, **Dizhur, D.**, & **Horspool, N.**, Fragility and vulnerability curves of unreinforced masonry buildings using empirical data from the 2010/11 Canterbury earthquakes.

Aigwi, E., **Ingham, J.**, **Filippova, O.**, & Phipps, R., Unintended consequences of the earthquake-prone building legislation: An evaluation of city centre regeneration strategies in two New Zealand's provincial areas.

Akers, K., Understanding the need for, availability of, and interpretation of information by the public during large scale hazard events. Co-production role.

Alger, B., Fostering natural hazard resilient communities through gameplay.

Allen, N., **Wilson, T.**, Kennedy, B., **Scott, A.**, & Stewart, C., Multi-volcanic hazard impact assessment for residential buildings in the Auckland Volcanic Field.

Bae, S., On-demand web-enabled ground motion simulation and seismic hazard information.

Bhanu, V., **Chandramohan, R.**, & **Sullivan, T.**, Investigating the influence of earthquake ground motion duration on structural dynamic deformation capacity.

Bolomope, M., **Filippova, O.**, Amidu, A., & Levy, D., Expectations vs reality: Institutional analysis of property investors' decision-making behaviour in a seismically active country.

Boston, M., Creating a tool for rapid holistic assessment and rating of post-earthquake hospital functional.

Bradley, B., Huang, J., Motha, J., Tarbali, K., Lee, R., Bae, S., Polak, V., Zhu, M., Schill, C., Paterson, J., & Lagrava, D., Cybershake NZ v19.5: New Zealand simulation-based probabilistic seismic hazard analysis.

Brenin, M., Stewart, C., Horswell, J., **Johnston, D.**, McLaughlin, V., Kaiser, L., & **Wotherspoon, L.**, Minimising public health risks from human waste after a large Wellington Fault earthquake: What shall we do with the poo?

Bueker, F., Parr, M., **Elwood, K.**, & Bull, D., Development and testing of hollow-core retrofits.

Campbell, E., Communicating earthquake risk information to Tamariki: Challenges and opportunities in a digital world.

Cappellaro, C., **Cubrinovski, M.**, Bray J, **Chiaro, G.**, Riemer, M., & **Stringer, M.**, Cyclic undrained DSS testing of Christchurch sandy silty soils.

Cave, A., **Jeong, S.**, Stolte, A., & **Wotherspoon, L.**, Dynamic site characterisation of the Waikato basin using passive and active surface wave methods.

Cetiner, B., Koc, E., Taciroglu,E., & Soibelman, L., A data-driven approach for granular simulation of potential earthquake damage to bridge networks and resulting decreases in mobility.

Chiaro, G., **Palermo, A.**, Bansiak, L., Granello, G., Tasalloti, A., & Hernandez, E., Eco-rubber seismic-isolation foundation systems: A sustainable and cost-effective way to build resilience.

Chigullapally, P., **Wotherspoon, L.**, Wood, J., **Hogan, L.**, & **Pender, M.**, Seismic response of an instrumented reinforced concrete bridge subjected to varying excitation levels.

Collins, T., & Eade, C., Legal responsibility for the mitigation of risks associated with earthquakes.

Darling, M., **Wilson, T.**, **Bradley, B.**, **Orchiston, C.**, & Adams, B., Understanding disaster risk exposure to visitors to the South Island of New Zealand.

De Francesco, G., & **Sullivan, T.**, Development of a local approach for tangent-stiffness-proportional damping model.

de la Torre, C., **Bradley, B.**, & **McGann, C.**, 3D seismic site response with soil heterogeneity and wave scattering.

Dong, W., & **Li, M.**, A preliminary study on cyclic behaviour of SFS dowelled connections in glulam frames.

Elwood, K., Puranam, A., Lee, H., Tsai, R., Hsiao, F., Hwang, S., & Suzuki, T., Testing of a seven-storey reinforced

concrete soft-storey structure with torsional and damaged irregularities under unidirectional ground motion.

Filippova, O., & **Sullivan-Taylor, B.**, Balancing [EQPB] act: Heritage preservation, regulations and their impact on the future of small towns.

Francis, T., **Sullivan, T.**, & Filiatrault, A., A value case for seismic isolation of residential buildings.

Fraser, B., Temporal drivers of disaster risk and resilience in rural New Zealand.

Galvez, F., **Dizhur, D.**, & **Ingham, J.**, Analytical and numerical prediction of the vulnerability of post-earthquake observed URM macroblocks.

García, M., Governing community resilience: Interconnections between community resilience, well-being and capitals.

Garcia, E., & Bray, J., Capturing the influence of soil density on surface fault rupture propagation using the discrete element method.

Gray, L., **Becker, J.**, MacDonald, C., & **Johnston, D.**, Conspicuous invisibility in disaster risk reduction.

Harrison, S., Capturing impacts, experiences, and behaviour during disaster: An online participation and crowdsourcing approach for resilience.

Hashemi, A., Bagheri, H., Yousef Beik, S., Zarnani, P., & Quenneville, P., The equivalent ductility approach for designing the structures using Resilient Slip Friction Joints (RSFJs).

Haymes, K., **Sullivan, T.**, & **Chandramohan, R.**, A practice-oriented method for predicting elastic floor acceleration response spectra.

Hewa Algiriyage, N., **Prasanna, R.,** Stock, K., **Hudson-Doyle, E.**, & **Johnston, D.**, Identifying research gap and opportunities in the use of multimodal deep learning for emergency management.

Hoang, T., & **Noy, I.**, Prioritising earthquake retrofitting in the high seismic risk city of Wellington.

Hopkins, W., **Collins, T.**, & Jacomb, K., Regulating seismic risk in existing multi-storey buildings in NZ: The Wellington case study.

Horspool, N., **Elwood, K**., **Johnston, D.**, Deely, J., & Ardagh, M., Cause of injury and death from recent New Zealand earthquakes.

Kahandawa, R., Domingo, N., Chawynski, G., & **Uma, S.**, Investigation into the factors affecting costs of earthquake damage repair work.

Kearns, N., & Blake, D., Stories from a Hazardscape: Living with chronic illness in Petone.

Khansari, T., Hayden, C., & **Wotherspoon, L.**, Liquefaction constitutive model validation using pore pressure records from the Canterbury Earthquake Sequence.

Kowal, A., **Stirling, M.**, Gorman, A., & **Wotherspoon, L.**, Strong ground motions simulations for Dunedin: Recent progress.

Lambie, E., Campbell, E., **Johnston, D.**, **Elwood, K.**, Stephens, M., **Uma, S.**, **Prasanna, R.**, **Becker, J.**, Rangika, N., Tan, M., Imtiaz-Syed, Y., **Hudson-Doyle, E.**, & **Hopkins, J.**, Smart resilient cities.

Lee, R., & **Bradley, B.**, Hybrid broadband ground motion simulation validation of New Zealand earthquakes with an updated 3D velocity model and modified simulation methodology.

Lew, S., **Wotherspoon, L.**, **Hogan, L.**, & Al-Ani, M., Assessment of the historic seismic performance of the New Zealand bridge stock.

Lin, A., **Wotherspoon, L.**, Blake, D., **Bradley, B.**, & Motha, J., Liquefaction exposure across New Zealand transport networks.

Little, M., Rathje, E., DePascale, G., & Bachhuber, J., Assessment of empirical lateral spreading displacement models using data from the 2011 Christchurch earthquake.

Loghman, V., **Bradley, B.**, **Chandramohan. R.**, & **McGann, C.**, Validation of ground motion simulations via response history analysis of special moment resisting frames using an automated workflow.

Lu, Y., **Henry, R.**, **Elwood, K.**, **Rodgers, G.**, Zhou, Y., Gu, A., & Yang, T., ILEE-QuakeCoRE shake table test on a full-scale low-damage concrete wall building.

Marafi, N., Berman, J., Makdisi, A., & Eberhard, M., Effects of simulated magnitude 9 earthquake motions on reinforced concrete wall structures in the Pacific Northwest.

McClure, J., Ferrick, M., & **Johnston, D.**, Risk judgments and social norms: Do they relate to preparedness after the Kaikōura earthquakes.

McLaren, L., **Johnston, D.**, **Hudson-Doyle, E.**, **Becker, J.**, & Beatson, A., Community science as a tool for increased disaster resilience.

Miranda, C., Raftery, G., Toma, C., & **Johnston, D.**, The effectiveness of retrofit technologies in wooden-framed houses in Wellington.

Moratalla, J., **Uma, S.**, Dellow, S., Compilation and comparison of pipe fragility relationships based on liquefaction severity.

Motha, J., Loghman, V., **Bradley, B.**, Lee, R., Lagrava, D., Schill, C., Zhu, M., & Paterson, J., Automated workflow for validation of ground motion simulations using conventional and complex intensity measures.

Munoz, G., **Henry, R.**, & **Elwood, K.**, Repairability of earthquake damaged reinforced concrete walls.

Neill, S., Lee, R., & **Bradley, B.**, Ground motion simulation validation with explicit uncertainty incorporation for small magnitude earthquakes in the Canterbury region.

Nguyen, T., Lee, R., Juarez, A., & **Bradley, B.**, Synthetic study of full waveform seismic tomography for geophysical velocity model in Canterbury region based on the Adjoint-Wavefield method.

Nicolin, E., **Dempsey, D.**, & Kah, J., What should Auckland expect from a Magnitude 7 Hauraki Rift Earthquake?

Ntritsos, N., & **Cubrinovski, M.**, System response of liquefiable deposits.

Nwadike, A., Wilkinson, S., & **Clifton, C.**, Building code amendment and compliance in post-disaster reconstruction in New Zealand.

Omoya, M., & Burton, H., Bayesian updating of earthquake-induced building downtime parameters.

Opabola, E., & **Elwood, K.**, Experimental and analytical investigations of uncertainty in seismic response of reinforced concrete components.

Orumiyehei, A., Simplified seismic risk assessment of systems with two failure mechanisms using the improved SAC/FEMA approach.

Pascua, C., & **Henry, R.**, Review of recently constructed buildings with dual systems combining steel frames and concrete walls.

Pastor, J., **Filippova, O.**, **Elwood, K.**, & **Noy, I.**, Making Wellington [earthquake] resilient: Creating building inventory dataset for seismic risk assessment and management.

Pepperell, B., Leadership challenges and opportunities in extreme contexts.

Plotnikova, A., **Wotherspoon, L.**, & Beskhyroun, S., Dynamic behaviour of reinforced concrete bridges in freezing conditions.

Pujol, S., & Gale, D., Estimation of seismic drift demands in torsional structures.

Ramhormozian, S., **Clifton, C.**, Yan, Z., **MacRae, G.**, **Dhakal, R.**, Quenneville, P., Zhao, X., Jia, L., & Xiang, P., Shaking table test of a near full scale low damage structural steel building: Structural aspects.

Rhodes, A., Keepa, C., **Cubrinovski, M.**, & Krall, T., Seismic site response at CentrePort, Wellington.

Rickard, H., **Noy, I.,** Lambie, E., & Owen, S., Development of a GIS platform for multi-disciplinary community databases to enable earthquake resilience and research.

Rushton, A., **Kenney, C.**, **Phibbs, S.,** & Anderson, C., "Puck it up and do your role": Men and the Kaikōura earthquake.

Sarkis Fernández, A., **Sullivan, T.**, Brunesi, E., & Nascimbene, R., Numerical seismic performance assessment of precast pre-stressed hollow-core concrete floors.

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