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Te Hiranga Rū QuakeCoRE formed in 2016 with a vision of transforming the earthquake resilience of communities throughout Aotearoa New Zealand, and after five years of 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 fifth 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 develop and apply world-leading science to the consideration of the ground motions that result from major earthquakes. Over the past five years the methods applied to address this phenomena have transformed from simple empirical estimates based on globally-recorded earthquakes, to earthquake- and site-specific models based on representing the three-dimensional physics of earthquake rupture and seismic wave propagation. The technical expertise of its researchers, as well as the convening authority of Te Hiranga Rū QuakeCoRE have also enabled it to play a valuable role in the on-going development of the National Seismic Hazard Model, led by our Partner Organisation, Te Pū Ao GNS Science. Similarly, Te Hiranga Rū QuakeCoRE researchers have applied leading methods in large-scale experimental tests to understand the characteristics of Aotearoa New Zealand’s bridges in-situ; have partnered directly with other agencies to further quantify the performance and failure mechanisms of Aotearoa New Zealand’s precast concrete multi-storey building stock, and continue strong international collaborations at some of the world’s largest experimental structural engineering facilities. Te Hiranga Rū QuakeCoRE has also significantly increased its activities and ambition over the past several years in the development and integration of mātauranga Māori throughout the Te Hiranga Rū QuakeCoRE research programme and its associated activities.

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 marks the end of the first funding period, and highlights several examples of outstanding university research students who have benefited from Te Hiranga Rū QuakeCoRE collaboration and now are blazing trails in academia, the public and private sectors. As we establish 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.
Chair’s Report 2020

Tēnā koutou

Since inception in 2016, the research and engagement activities of Te Hiranga Rū QuakeCoRE have pushed Aotearoa New Zealand to the global forefront of earthquake disaster resilience. The successful funding rebid this year ensures that the programme can build on achievements through until 2028 and beyond, and further establish multi-institutional research programmes throughout Aotearoa New Zealand with links to international networks.

Over the last year, Te Hiranga Rū QuakeCoRE has continued to mature as Aotearoa New Zealand’s Centre of Research Excellence for earthquake resilience research. Over the period covered in this Annual Report we have seen a concerted effort to deepen the understanding of how Te Ao Māori can benefit engineering thinking and planning, with research that explores the benefits that arise when non-Māori researchers have an understanding of Māori cultural values and include Māori at the conceptual stage of projects. The establishment of Te Apārangi o Hiranga Rū (Māori Advisory Board) was a significant step and I’d like to acknowledge and thank specifically the founding members: Tā Mark Solomon (Chair), Shane Graham, Diane Bradshaw and Marama Muru-Lanning.

We have also seen effort channelled to explore better linkages with industry, so that the benefits of research are accrued directly into communities and infrastructure. That’s the end game after all – more resilient communities in Aotearoa New Zealand.

Some of the other highlights have included:

- Advancements in ground-motion modelling, providing realistic simulations to provide practical help for researchers, planners, responders and decision makers;
- The innovative testing of the decommissioned Whirokino bridge to assess performance in different scenarios, enabling useful modelling that can be applied to other similar infrastructure; and
- Key contributions to the National Seismic Hazard Model, which underpins key planning factors that are critical for building resilient cities and infrastructure.

As these examples illustrate, the greater the ebb and flow of knowledge between academia, communities and industry, the greater the benefits to Aotearoa New Zealand and other nations. Collaboration is at the heart of te mahi o Te Hiranga Rū QuakeCoRE. He waka eke noa.

COVID-19 has sorely tested Aotearoa New Zealand’s economic and social wellbeing. It has also tested the resilience of Te Hiranga Rū QuakeCoRE. The response to that test has overwhelmingly been positive. Students and supervisors have seized opportunities that have arisen out of restrictions through making the most of unexpected time in Aotearoa New Zealand. This in turn has simultaneously strengthened international bonds and broadened research horizons.

Looking ahead, the next phase will provide significant advancement and application of new smart technologies to earthquake engineering, and the social and economic mitigation of future earthquake impacts. This is a privileged position, and I am grateful to Brendon Bradley (Director), to David Johnston (Deputy Director) and Ken Elwood (Research Director) for their leadership and vision in bringing us here. I would also like to acknowledge the wider team for their support and contributions. Thank you.

Thank you to the Board for their wisdom, guidance and leadership, and particularly outgoing Board members Dean Kimpton (chair, Tuhura Consulting), John Hare (Holmes Group), John Reid (Ngāi Tahu Research Centre), Jan Evans-Freeman (University of Canterbury), Bryony James (University of Auckland) and Mary Comerio (University of California, Berkeley, USA). I look forward to continuing the work with our current members, Tā Mark Solomon, David Brunsdon, Ian Wright, Wendy Saunders, Rosalind Archer and Ellen Rathjie.

On behalf of the Board, we are looking forward to an exciting next 12 months and beyond.

He toka tū moana, ara he toa rongonui [strong like a rock in the rapids].

Mike Mendonça, MBE
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 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 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.
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.

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.
Flagship Programmes

1. **Ground motion simulation and validation**
   Leader: Brendon Bradley | Deputy Leader: David Dempsey | 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.

2. **Liquefaction impacts on land and infrastructure**
   Leader: Misko Cubrinovski | Deputy Leaders: Rolando Orense & Sjoerd van Ballegoooy | Industry Representative: Sjoerd van Ballegoooy
   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.

3. **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.

4. **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.

5. **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.
Technology Platforms

1. **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.

2. **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.

3. **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.

4. **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.
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 Project

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.
Moving Ground

When the ground moves beneath our feet there is a fun-park of physics at play: pressure, friction, energy, speed, distance, time – all interacting to produce a unique felt experience for each earthquake. With so many factors to ground shaking how do we ensure people will be safe? How do we make sensible land use plans? What engineering design standards are appropriate? Enter the field of ground motion prediction where there is change afoot...

Ground motion prediction has traditionally relied on past observations to estimate what will happen in future earthquakes. Principal Investigator of Te Hiranga Rū QuakeCoRE’s Ground Motion Simulation and Validation Programme, Brendon Bradley, recalls feeling like he was using a blunt instrument when he started studying site-specific ground motions from the 2010-2011 Canterbury Earthquake Sequence. That’s when he decided to bring physics-based ground motion simulations, showing promise overseas, to Aotearoa New Zealand.

Ground motion simulations use a 3D model of the earth’s crust with different soil and rock types and characteristics of known faults. Based on what is known about seismic waves and how they travel, such simulations can predict how the ground will move at a given site in any earthquake. With supercomputers and ever-more-detailed crustal models, the improvement over old empirical methods is that shaking can be estimated with confidence for conditions we haven’t experienced before.

QuakeCoRE researchers have been improving the prediction capabilities of ground motion simulations by testing results against thousands of real earthquakes. New Zealand contributed to this validation work in a unique way – by having a large, complicated earthquake at the outset of the research programme. The 2016 Kaikōura Earthquake, with a magnitude of 7.8, ruptured over 20 faults in 2 minutes and, at a big picture scale, ground motions simulated by QuakeCoRE were close to measured ground motions.
Always moving to improve seismic hazard knowledge, QuakeCoRE researchers have now simulated earthquakes from faults in New Zealand's National Seismic Hazard Model. These simulations make up Cybershake, an initiative started in California to harness the predictive power of physics-based ground motion simulations for the benefit of seismic hazard analysis. Lessons from Cybershake NZ will be incorporated into the National Seismic Hazard Model as part of an update due in 2022.

There is more ground to cover, but Brendon can see a time when 3D simulations replace empirical methods entirely. QuakeCoRE is iteratively bringing New Zealand closer to having no surprises when a large earthquake strikes. We will know what ground shaking to expect and, with uptake by policy-makers, planners, and engineers, we will have prepared accordingly – thereby making New Zealand more resilient.
QuakeCoRE meets Rūaumoko

"Ka mate whare tahi, ka ora whare rua
With one house we are weak, with two houses we are strong

"Using just our own minds we are weak. However, if we use our minds combined with the minds of the community and those from other worldviews, we expand our horizons and become stronger." This is how Nona Hohepa-Taute explained the above whakatauki at the 2019 Pacific Conference on Earthquake Engineering. Nona, who is a lecturer and PhD student at the University of Auckland's Engineering Faculty, and thoroughly immersed in his Māori culture, demonstrates the advantages in using both mātauranga Māori and Pākehā science to make Aotearoa New Zealand a better place to live.

Nona’s research explores the benefits that arise when non-Māori engineers have an understanding of Māori cultural values and include Māori at the conceptual stage of projects. The trust and respect that stems from mutual understanding increases the likelihood that engineering projects will be successful. Bicultural projects not only improve resilience to natural hazards and the sustainable use of natural resources, but also provide solutions that uphold and strengthen Māori connection to their culture and environment.

As a starting point, Nona encourages non-Māori earthquake engineers in Aotearoa New Zealand to learn about Rūaumoko – the Māori god of earthquakes, volcanoes and geothermal activity. This may seem a far cry from learning formulas to calculate building strength – he is not suggesting mātauranga replaces the Western discipline of engineering – but rather, that by expanding horizons to incorporate mātauranga, all of society benefits. Learning about Rūaumoko’s relevance to Māori opens the door to understanding the interconnectedness that Māori culture has with natural forces and resources – beneficial to New Zealand as a whole.
Te Hiranga Rū QuakeCoRE Principal Investigator Jason Ingham recalls the early days of QuakeCoRE as very white and very male. To fulfil funding obligations to mātauranga Māori he wanted to work on seismic resilience of marae buildings but he wasn’t sure how to start. Jason has now learnt: first you build relationships then you build a research plan. From learning his pepeha to doing the Rūaumoko haka, Jason has been thoroughly enriched and made close colleagues with whom he can now do truly collaborative, multicultural, interdisciplinary research.

QuakeCoRE research into seismic assessment of marae buildings is following a kaupapa Māori approach. A predominantly Māori team of building experts have laid out the justifications and recommendations for changes to building status, methods and capabilities that will ensure culturally appropriate treatment of earthquake-prone marae buildings. There is more to come, but this work, published in the Philosophical Transactions of the Royal Society, is a clear illustration that when it comes to resilience to Rūaumoko’s rumblings, the more worldviews, the better.
Aotearoa New Zealand, with its mountainous terrain and numerous rivers, is a land of many bridges. Thousands of bridges not only keep communities connected but also carry essential services like water, power and communication cables. Many New Zealand bridges were built before modern design codes so we don’t know how they’ll perform in large earthquakes. Te Hiranga Rū QuakeCoRE researchers are making the most of a novel opportunity to find out.

Associate Investigator Lucas Hogan is always on the hunt for old bridges. So, for Lucas and his engineering colleagues at the University of Auckland, the proposed demolition of the original Whirokino bridge was an exciting discovery.

The 1.2-kilometre-long trestle bridge, spanning the Manawatū River and floodplain south of Foxton, was deemed too narrow for today’s traffic and has now been replaced. The old bridge represented a rare chance to test a long bridge after 80 years of service and with its piles still in the ground.

To replicate strong ground shaking, piles of the old bridge were pushed and pulled using a hydraulic jack to see how they would perform and what sort of damage they would experience. Columns will be tested in a similar way in the lab later this year. Key to the value of this research is that the old Whirokino bridge was built in 1939 to standard design and construction techniques. Therefore, test results will be useful for exploring the strength of many similar-aged structures.
The fate of the bridge piles was of great interest to Waka Kotahi NZ Transport Agency, who are responsible for maintaining more than 4,500 bridges to keep New Zealand roads open. Close collaboration was also essential between the researchers and bridge demolition contractors. The research was funded by EQC and QuakeCoRE.

The good news is that the piles held strong in the face of powerful forces. This bodes well for many similar bridges. Once column testing is complete, there will be a detailed prognosis of bridge strength with insights into assessment techniques and retrofitting needs. Fragility modelling is underway to estimate the vulnerability of this bridge type to different levels of earthquake hazard.

With this kind of knowledge, it becomes easier to appropriately prioritise bridge strengthening or replacement. And from a risk management perspective, it becomes possible to identify the weak links in the roading network and make plans to minimise isolation of communities before the next damaging earthquake.
Knowing Our Hazards

The first step towards managing our risks effectively and making Aotearoa New Zealand a safe place to live, is to know our hazards. The National Seismic Hazard Model (NSHM) is a way of encapsulating what scientists know about the location of active faults in New Zealand, the probability of earthquakes occurring away from known faults, the magnitude and frequency of earthquakes and how much the ground will shake in different parts of the country over varying time periods. It provides an estimate of earthquake hazard.

Even at a glance, maps from the NSHM show us that Northland and eastern Southland are less shaky places than the rest of the country. At a more detailed level, the NSHM provides the basis for policy making and land use planning by central and local government, risk assessments for the insurance industry and guidance for setting engineering design standards.

Given New Zealand's stark experience of earthquakes over the last decade and rapid advances in technology, there is a lot of new data, understanding, and modelling capability, that is not incorporated in the 2010 version of the NSHM. In 2019 the Ministry for Business, Innovation, and Employment (MBIE) and EQC commissioned GNS Science to revise the NSHM. Te Tauira Matapae Pūmate Rū i Aotearoa, a GNS-led research programme, will be completed in August 2022. GNS Principal Scientist Matt Gerstenberger is leading the programme with about 50 national and international researchers contributing. Matt says there is an integrated involvement of end users – for the first time for a seismic hazard model internationally, insurance brokers, policy makers, engineers are part of the Technical Advisory Group.

Many Te Hiranga Rū QuakeCoRE researchers are involved with the revision. As New Zealand’s Centre for Earthquake Resilience, QuakeCoRE is keen to support uptake of the NSHM and is well-placed to facilitate engagement with the engineering community in particular. QuakeCoRE started this process by hosting a NSHM workshop at the QuakeCoRE Annual Meeting in 2020 with another planned for the 2021 meeting.

A new initiative to compliment this NSHM revision is MBIE’s Seismic Risk Working Group (SRWG). This is a think tank of industry and academic experts, many from the QuakeCoRE community, who are working in tandem with the NSHM update to provide advice on how to take hazard outputs and put them into engineering practice. In particular, this advice will give direction on how to update the building code and it will enable MBIE to act quickly to make change.
As Matt says, “There will always be uncertainty in our knowledge of how the earth works but right now we’re in the process of producing a model that best reflects our current understanding and capabilities. A modern NSHM is crucial for making decisions that matter, and the SRWG provides a vehicle for us to get the NSHM science into practice in an appropriate manner.”
Safer Buildings

There are few sights more chilling after an earthquake than that of multistorey buildings with collapsed floors – a pile of concrete pancakes between which people used to work and live. Building failures are not restricted to developing countries or old buildings; the 1994 Northridge Earthquake in California had many examples and New Zealand witnessed collapses in the 2011 Christchurch Earthquake and partial collapse of a very modern building in the 2016 Kaikōura Earthquake.

Failure of precast concrete floors is a concerning issue for New Zealand because such floors have been used extensively in mid-rise buildings all around this seismically active country. The ReCast Floors (REtrofit of preCAST FLOORS) Project, initiated in late 2018, has found solutions for making them safer. With increased urgency due to the damage sustained in the Kaikōura Earthquake, researchers have developed methods for retrofitting precast concrete floors in existing buildings to improve their performance in earthquakes.

Not satisfied with theoretical solutions alone, the project team put their designs to the test. At the University of Canterbury’s Structural Engineering Laboratory, parts of buildings were pushed and prodded as if they were in the Kaikōura or Northridge earthquakes. This “super-assembly” testing, among the largest in the Southern Hemisphere, involved a full-scale replica of one quarter of a single storey from a 10-storey office building with different retrofit designs installed.

Large-scale Precast Floor Experimental Testing.
Photo credit: Corey Blackburn
for different tests. Smaller “sub-assembly” tests (using only beams and precast floor units) were carried out at the Structures Testing Laboratory at the University of Auckland.

One of QuakeCoRE’s founding concepts – to share expertise and facilities for the benefit of New Zealand – has been realised in the ReCast Floors Project. BRANZ was the major funder with additional support from EQC, QuakeCoRE, and the Concrete New Zealand Learned Society. The project team included researchers, laboratory technicians, practitioners, and students. Collaboration with the structural engineering industry was at the core of the work. As Principal Investigator Ken Elwood expressed, “It might be simpler to do research on your own but outcomes are much more useful if you interact with industry along the way.”

A big gap has been filled by this project: engineers now have guidance on how to retrofit precast concrete floors in existing buildings. Further safety assurance has been provided by full scale testing. The collaborative approach has ensured that the recommended retrofit solution is widely applicable – increasing its uptake and ultimately leading to safer buildings sooner and fewer lives lost in the next big earthquake.
Seismometers in Schools

When the magnitude 8.1 Kermadec Earthquake occurred on 5 March 2021, the children of Matatā Public School knew what to do. Although there was no strong shaking on the mainland of Aotearoa New Zealand, they knew it was time for a tsunami hīkoi – time to get to high ground in case of waves inundating their school.

The school was highly prepared because, as well as their regular drills, they had hosted the national earthquake drill and tsunami hikoi – ShakeOut – in October 2020. Civil defence officials and scientists joined the children to “drop, cover, and hold” in a livestreamed exercise in which 670,000 New Zealanders practised their earthquake response. The school had also been given their own seismometer to monitor earthquakes.

Te Hiranga Rū QuakeCoRE researchers have installed seismometers in 11 schools so far with plans to expand. Giving seismometers to schools is not a new idea, but technological advances, such as those provided by Raspberry Shake...
Students test the Raspberry Pi Seismometer through floor vibration. Photo credit: David Johnston

(who make seismographs powered by raspberry pi computers), are making it easy for schools to become part of a global seismic monitoring network. However, as Principal Investigator David Johnston explains, “It’s not all about the instruments. The seismometers are a starting point for building relationships and having conversations about natural hazards.”

Scientists from Massey, Canterbury, and Victoria Universities, and GNS Science are introducing natural hazard activities into schools as part of the seismometer roll-out. Interaction with scientists can help children prepare for events, improve their understanding of natural hazards, contribute to science advances, and be aware of different careers. Children are also likely to take preparedness knowledge into homes. Connecting with the school’s stakeholders and leaders, particularly the principal, board of trustees and mana whenua, has been critical to success. Working with schools aligns with QuakeCoRE’s vision of a resilient country where communities are prepared for disasters and the preparation has been informed by excellent research.

QuakeCoRE is collaborating with other research programmes to maximise the potential of school-based seismometers. Bay of Plenty schools are helping monitor seismic activity of the Taupō supervolcano for the programme ECLIPSE (Eruption or Catastrophe: Learning to Implement Preparedness for future Supervolcano Eruptions). Wellington schools are helping pilot a move towards citizens monitoring cities in the Resilience to Nature’s Challenges Programme.

After the ShakeOut exercise at Matatā School in 2020, teachers reported that some children were unsettled by the idea of a big earthquake or tsunami. However, when the real event struck in March 2021, children faced it with calm confidence because they had practised. As David reflects, “This is exactly the outcome we’re hoping for after running preparedness exercises – not only will children be physically safe but they’ll also feel empowered by the knowledge they have.”
Academic Opportunities

Te Hirangi Rū QuakeCoRE is developing the next generation of researchers by funding PhD scholarships and bridging gaps between PhD, postdoctoral fellowships and academic positions. QuakeCoRE has a strong mentoring ethos and the multi-institutional community provides diverse opportunities for students. QuakeCoRE is pleased to see some of its original students continuing their research in academic careers.
Shannon Abeling is a born and bred QuakeCoRE Scholar. She came from California in the first round of QuakeCoRE PhD scholarships to study the behaviour of unreinforced masonry buildings in the Canterbury Earthquake Sequence. Her supervisor, QuakeCoRE Principal Investigator Jason Ingham encouraged her to do extra-curricular activities. This led her to being a founding member of the QuakeCore Emerging Researchers Chapters (QERC) in 2016. She was president of the Auckland chapter for two years, then vice-president and outreach officer. Shannon is now underway with postdoctoral research into resilient buildings. “QuakeCoRE opened up opportunities to talk with researchers outside my field. Winning the Director’s Award in 2019 raised my profile and ultimately led to new collaborations and a postdoctoral opportunity”. 

Photo credit: Stephen Hussey
Marion Tan also came from overseas to do her PhD in New Zealand. QuakeCoRE made her experience less daunting because she joined an existing research community with good connections to industry. She was involved with the Wellington Chapter of QERC and became its president in 2017. Marion recently received a QuakeCoRE Proposal Development Grant enabling her to do groundwork for her next academic endeavour. She is applying for funding to develop a best practice framework for programs that place seismometers in schools. Marion aims to continue researching user-centric perspectives on technology that keeps people safe, because, as she argues, “technology is only useful if users know how to use it”.

Photo credit: Alicia Cui
Robin Lee is a lecturer in Earthquake Engineering at the University of Canterbury. He credits his position to the mentorship and good working relationship he has with QuakeCoRE Director Brendon Bradley. Robin started his PhD before QuakeCoRE but his research on ground motion simulations was well aligned and quickly folded into the programme. Robin says “QuakeCoRE allowed me to collaborate with top researchers, both nationally and internationally, and provided me with an unprecedented opportunity to grow and establish myself as a researcher.” QuakeCoRE Proposal Development Grants have supported Robin with his recent Marsden Fast-Start application.

By supporting researchers such as Shannon, Marion and Robin, QuakeCoRE is ensuring a succession of academics dedicated to understanding more about earthquakes and how to live safely in a seismically active country.
Bridge to Industry

As a Centre of Research Excellence, Te Hiranga Rū QuakeCoRE contributes to Aotearoa New Zealand’s development in various ways, not least by providing pathways for QuakeCoRE scholars to find employment in industry.

Cuong Nhu Nguyen, motivated by the typhoon disasters he witnessed in Vietnam, and with a Master’s degree in economics from the University of London, came to New Zealand in 2016 to study the economics of disaster recovery and earthquake insurance. He did an EQC-funded PhD supervised by Ilan Noy, Chair in the Economics of Disasters and Climate Change at Victoria University of Wellington. For Cuong, QuakeCoRE provided an insight into the wide range of earthquake-related topics being addressed in New Zealand and the annual conferences were a chance to meet a lot of key players.

The skills he gained during his PhD – like tackling the big dataset of Canterbury earthquake insurance claims – have enabled him to contribute to solving pressing problems as he’s moved into government jobs. At the Ministry of Business Innovation and Employment he produced forecasts (and even nowcasts) of the economic impacts of Covid-19 lockdowns. Cuong is now at the Reserve Bank where he is running stress tests on risks as diverse as climate change, cyber-attacks and rising house prices.
After a PhD and postdoctoral research at the University of Canterbury, Sarah Barrett has been pleased to discover that the learning, researching and problem-solving of academia can continue into industry jobs. Sarah is enjoying working at BECA where she is able to apply her liquefaction research in ways that directly impact people’s lives. She also appreciates opportunities to branch out into other fields such as slope stability and debris flow modelling and helping councils with natural hazard assessments.
Ananth Balachandra went straight into consulting as a Geotechnical Engineer after gaining a Civil Engineering degree in 2011. In this role, he enjoys working on and bringing to life roading, building and other infrastructure projects. It was a QuakeCoRE Masters project that encouraged Ananth to make some time for research in addition to working full time at Tonkin and Taylor. His thesis topic was to validate numerical simulations of buildings interacting with liquefiable soils against centrifuge experiment results. The QuakeCoRE postgraduate experience enabled him to pursue his interest in geotechnical earthquake engineering and delve deeper into a topic than is possible under the commercial imperatives of the workplace. Ananth is now involved in providing industry guidance as the New Zealand Geotechnical Society’s representative for updating the Earthquake Geotechnical Engineering Modules.

As these experiences illustrate, the greater the ebb and flow of knowledge between academia and industry, the greater the benefits to New Zealand.
Lockdown Opportunities

“In the middle of difficulty lies opportunity”. Einstein’s words have been ringing true for international students recently. Since the Covid-19 pandemic led to travel restrictions, students have had to adapt to changing circumstances. Te Hiranga Rū QuakeCoRE has had to get smarter about operating as a virtual organisation and providing a sense of community from a distance.

Shakti Raj Shrestha came to Aotearoa New Zealand in 2018 to do a PhD on the cordons that get erected around damaged zones after earthquakes. As Shakti got deeper into his topic, he realised that the web of legal, economic, ethical and political considerations he was addressing were unfolding around him in daily life. “Cordons are like inside out lockdowns. Authorities want to protect the public; after a while people just want to get on with life.”

Shakti has been locked down in Nepal and New Zealand. Caroline Orchiston and Shakti’s other supervisors were supportive and inventive about where he worked so a cordon case study from Nepal became part of his thesis. Although Shakti found it hard to be productive while isolated, lockdowns have resulted in a stronger international perspective to his research.
Ryo Kuwabara is researching earthquake-damaged buildings to clarify when they can be re-occupied or if they need to be repaired or demolished. Ryo received a PhD scholarship from the University of Auckland in 2020 but has had to stay in Japan. With the help of supervisors Ken Elwood and Lucas Hogan, Ryo made the most of being in the “wrong” place at the right time. Collaboration between the University of Auckland and the Earthquake Research Institute at the University of Tokyo enabled Ryo to join the project team for a full-scale test of building strength using the world’s largest shake table. Data from this test will now be key to Ryo’s thesis.

Ryo says the most important aspects to studying while isolated are to communicate regularly and manage your schedule to stay motivated. He has found QuakeCoRE’s online events useful but is looking forward to joining the community in person.
Ren-Jei Tsai has had to stay in Taiwan since starting his New Zealand PhD. He is investigating engineering solutions for making buildings safer in earthquakes. He aims to develop a procedure that makes coupled wall systems more ductile. Fortunately, Ren-Jei’s supervisor Rick Henry had links with Taiwan’s National Centre for Research on Earthquake Engineering. Ren-Jei has benefitted from this collaboration to learn from experts abroad and join useful experiments.

As QuakeCoRE students and supervisors seize opportunities that arise out of restrictions, they are simultaneously strengthening international collaborations and broadening research horizons.
Recognition Highlights

Lucy Kaiser

(GNS Science)

Lucy Kaiser won the GNS Science Excellence in Early Career Achievement Award in October 2020. This award recognises her important work using a kaupapa Māori approach to developing seismic and tsunami hazard education activities for kura ākonga (school students). Lucy also carried out collaborative work exploring the role of wāhine Māori researchers in the field of seismic research and made recommendations for alleviating some of the challenges to encourage more wāhine Māori into the physical sciences. The mahi was funded through partnerships between Te Hiranga Rū QuakeCoRE, Resilience to Nature’s Challenges, East Coast LAB and Massey University.

Photo credit: GNS Science
Greg MacRae won the Steel Construction New Zealand (SCNZ) Chair’s Award in November 2020. This award recognises individuals who have made a significant and lasting contribution to Aotearoa New Zealand’s structural steel industry. Greg is a University of Canterbury Te Hiranga Rū QuakeCoRE Associate Investigator. His work to improve structural resilience and implement low-damage design has been used in the Christchurch rebuild, throughout New Zealand and in other earthquake-prone countries. Frank Van Schaijik, SCNZ’s Chair, said, “Greg has... demonstrated a clear focus on finding the best structural solutions for both the community and the industry using safe, strong and resilient structures.”
## Financials

Data covers the period from 1 January 2020 to 30 June 2021

<table>
<thead>
<tr>
<th>Category</th>
<th>Total ($000s)</th>
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<td><strong>Net Surplus / (Deficit)</strong></td>
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## 2020 at a glance

*Data covers the period 1 January 2020 to 30 June 2021*

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<td>Invention disclosures</td>
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<tr>
<td>Patents granted</td>
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</table>
Community

Board

Dean Kimpton (Chair)
Mary Comerio
Jan Evans-Freeman
John Hare
Bryony James
Mike Mendonça
John Reid
Tā Mark Solomon

Tuhura Consulting
University of California, Berkeley
University of Canterbury
Holmes Consulting Group
University of Auckland
Wellington City Council
Ngāi Tahu Research Centre

International Science Advisory Panel

Mary Comerio (Chair)
Jack Baker
Tom O’Rourke
Ellen Rathje

University of California, Berkeley
Stanford University
Cornell University
University of Texas at Austin

Leadership Team

Brendon Bradley (Director)
David Johnston (Deputy Director)
Ken Elwood (Research Director)
Misko Cubrinovski
Caroline Orchiston
Wendy Saunders
Tim Sullivan
Liam Wotherspoon

University of Canterbury
Massey University
University of Auckland
University of Canterbury
University of Otago
GNS Science
University of Canterbury
University of Auckland
## Principal Investigators

Brendon Bradley  
Misko Cubrinovski  
Ken Elwood  
Anthony Hoete  
Jason Ingham  
David Johnston  
Erica Seville  
Tim Sullivan  
Liam Wotherspoon

University of Canterbury  
University of Auckland  
Massey University  
Resilient Organisations  
University of Canterbury  
University of Auckland

## Associate Investigators

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

Richard Apperley
Jawad Arefi
Hamish Avery
Sarah Barrett
Jeff Bayless
Nicholas Brooke
Dave Brunsdon
Des Bull
Nigel Colenso
Patrick Cummuskey
James Dismuke
Michael Drayton
Roger Fairclough
Helen Ferner
Matt Fox
Jeff Fraser
Reza Jafarzadeh
Weng Yuen Kam
Jared Keen
Angela Liu
Alan McMahon
Rebecca McMahon
Gareth Morris
Dan Neely
Matt Ogden

Aasha Pancha
Didier Pettinga
Dario Pietra
Aimee Rhodes
Andreas Skarlatoudis
Paul Somerville
Richard Voss
Rick Wentz

Aurecon
Beca
Canterbury Seismic Instruments
Beca
AECOM
Compusoft Engineering
Kestrel Group
Holmes Consulting
ABI Piers
Auckland Council
Golder Associates
Risk Management Solutions
Neo Leaf Global
NZSEE
Beca
Golder Associates
Auckland Council
Beca
Beca
BRANZ
Colliers International
Beca
Holmes Consulting
WREMO
Tonkin + Taylor

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.

Giovanni De Francesco
Adnan Djeffal
Trung Dung Nguyen
Max Stephens
Marion Tan
Lauren Vinnell

University of Canterbury
University of Canterbury
University of Canterbury
University of Auckland
Massey University
Massey University
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
Pavan Chigullapally  University of Auckland
Chris de la Torre    University of Canterbury
Riwaq Dhakal         University of Canterbury
Tom Francis          University of Auckland
Francisco Gálvez Gonzalez University of Auckland
Martin García Cartagena University of Otago
Anna Kowal           University of Auckland
Vahid Loghman        University of Auckland
Nikolaos Ntritsos    University of Auckland
Eyitayo Opabola      University of Auckland
Mehdi Sarrafzadeh    University of Auckland

Mohammadtaghi Aghababaei University of Auckland
Itohan Aigwi         University of Auckland
Marufa Akther        University of Auckland
Fransiscus Arfin     University of Auckland
Mohammad Bagher Asadi University of Auckland
Tyler Barton         University of Auckland
Vishvendra Bhanu     University of Auckland
Muhammed Bolomope    University of Auckland
Frank Bueker         University of Auckland
Ashley Cave          University of Auckland
Danny Chan           University of Auckland
Jackson Chen Yu      University of Auckland
Max Chirapattanakorn University of Auckland
Lucia Danzi          University of Auckland
Pavithran Devananthan University of Auckland
Wenchen Dong         University of Auckland
Thomas Dudek         University of Auckland
Michael Dupuis       University of Auckland
Cameron Eade         University of Auckland
Saeed Eyvazinejad Firouzsalari University of Auckland
Davide Forcellini    University of Auckland
Kevin Foster         University of Auckland
Amin Ghasemi         University of Auckland
Rosa Gonzalez Espinel University of Auckland
Lesley Gray          University of Auckland

University of Auckland
Massey University
University of Otago
University of Canterbury
University of Auckland
University of Canterbury
University of Auckland
University of Canterbury
University of Auckland
University of Canterbury
University of Otago
University of Canterbury
University of Canterbury
Victoria University Wellington
University of Canterbury
University of Canterbury
University of Auckland
University of Canterbury
University of Auckland
University of Auckland
University of Auckland
University of Otago
Yujia Han    University of Auckland
Sara Harrison    Massey University
Kieran Haymes    University of Canterbury
Asher Herrmann    University of Auckland
Rangika Hewa Algiriyage    University of Auckland
Thoa Hoang    University of Auckland
Arman Kamalzadeh    Massey University
Saanchi Kaushal    University of Auckland
Shreerdhar Khakurel    University of Auckland
Eseta Le’au    Massey University
Shong Wai Lew    University of Auckland
Robert Malcolm    Massey University
Lisa McClaren    University of Auckland
Romain Meite    University of Auckland
Catalina Miranda    University of Auckland
Richard Mowil    University of Auckland
Gonzalo Muñoz Arriagada    University of Auckland
Sunil Nataraj    Massey University
Sarah Neill    University of Auckland
Amirhossein Orumyehei    University of Auckland
Moriah Osborne    University of Auckland
Michael Parr    Massey University
Marie Claire Pascua    University of Auckland
Jacob Pastor    University of Auckland
Bruce Pepperell    University of Auckland
Kiran Rangwani    University of Auckland
Ebad Rehman    University of Auckland
Aimee Rhodes    University of Auckland
Julian Rincon Gil    University of Auckland
Ana Sarkis Fernandez    University of Auckland
Sulaiman Sarwary    University of Auckland
Subhechha Sharma    University of Auckland

Shakti Shrestha    University of Otago
Hossein Soleimankhani    University of Canterbury
Tomomi Suzuki    University of Auckland
Yasir Syed    University of Canterbury
Laura Tilley    University of Auckland
Qing Tong    University of Auckland
Christiana Torricelli    University of Auckland
Ren-Jie Tsai    University of Auckland
Clare Wilkinson    University of Auckland
James Williams    University of Auckland
David Wither    University of Auckland
Mohsen Yazdalian    University of Auckland
Majid Zakerinia    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.

- Sung Eun Bae    University of Canterbury
- Richard Ball    Resilient Organisations
- Emily Campbell  Massey University
- Alicia Cui      Massey University
- Alexandra Davis University of Canterbury
- Yen-Ko Huang    University of Canterbury
- Lucy Kaiser     Massey University
- Emily Lambie    Massey University
- Yiqiu Lu       University of Auckland
- Matt Luani      Massey University
- Jason Motha     University of Canterbury
- Sally Owen      Victoria University of Wellington
- James Paterson  University of Canterbury
- Claudio Schill  University of Canterbury
- Dong Son       University of Canterbury
- Andrew Stolte   University of Canterbury
- Ethan Thompson  University of Canterbury
- Tomas Uher      University of Auckland
- Syed Yasar Imtiaz University of Auckland

Support Staff

- Ruth Hartshorn  Operations Manager
- Brandy Alger    Outreach Coordinator
- Amy McGeddie    Administrator
- Siew Lee O’Brien Senior Finance 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
EU Centre  Pavia, Italy
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)  Christchurch, New Zealand
Quake Centre  Santiago, Chile
Research Centre for Integrated Disaster Risk Management (CIGIDEN)  Los Angeles, USA
Southern California Earthquake Center (SCEC)  Melbourne, Australia
Smart Structures Lab, Swinburne University of Technology

Partners

University of Canterbury (Host)
BRANZ
GNS Science
Massey University
Resilient Organisations
University of Auckland
University of Waikato
Victoria University of Wellington
Journal Publications (Direct Peer-Reviewed)


QuakeCoRE 2020 Annual Report


Rezaeian, H., Clifton, G., MacRae, G., & Lim, J. (2020). In-plane cyclic behaviour of composite floor slab diaphragm interfaces under high-shear demand. Journal of Constructional Steel Research, 167, 105838


**Published Conference Proceedings (Direct Peer-Reviewed)**


Clifton, G., Ferguson, W., Hodgson, M., & MacRae, G. (2020) Assessment and repair of damaged eccentrically braced framed buildings following a severe earthquake. 17th World Conference on Earthquake Engineering.

Clifton, G., Rezaeian, H., & MacRae, G. (2020) Demand, analysis and capacity of composite slab seismic diaphragms. 17th World Conference on Earthquake Engineering.


Djojo G., Clifton, G., Henry, R., & MacRae, G. (2020) Behaviour of the centralised rocking concentrically braced frame under static and dynamic loading. 17th World Conference on Earthquake Engineering.

Dong, W., Li, M., Lee, C., MacRae, G., & Abu, A. (2020) Cyclic tests of glulam frames with buckle restrained braces (BRBs). 17th World Conference on Earthquake Engineering.


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**QuakeCoRE Annual Meeting Posters**

97 posters were presented at the Te Hiranga Rū QuakeCoRE Annual Meeting in Whakatū Nelson from 8 – 10 December, 2020.

Aigwi, E., Filippova, O., Sullivan-Taylor, B.

Public perception of heritage buildings in Invercargill’s city centre


Te Hiranga Rū QuakeCoRE Quake Centre Outreach Programmes

Algiriyage, N., Prasanna, R., Stock, K., Doyle, E., Johnston, D.

Real-time Disaster Event Extraction from Unstructured Text Sources

Allen, N., Wilson, T., Kennedy, B., Scott, A., Stewart, C.

Multi-Volcanic Hazard Impact assessment for Residential Buildings in the Auckland Volcanic Field, New Zealand
Avendano-Uribe, B., Milke, M., Beaven, S., Hughes, M.  
The use of Participatory Modelling to integrate social and infrastructure resilience-building.

Bae, S., Huang, J., Bradley, B., Polak, V.  
Web Interfaces for Earthquake and Ground Motion Simulation Visualisation

Barnhill, D., Wilson, T., Hughes, M., Beaven, S., Schoenfeld, M., Chandratilake, S., Jack, H.  
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