Communicating earthquake engineering risks to youth in the South Island of New Zealand

B. Alger & A. Stolte
Te Hiranga Rū | QuakeCoRE, New Zealand.

A. *Lake-Hammond*
AF8 [Alpine Fault magnitude 8], South Island.

ABSTRACT

QuakeKit is a collaborative project through QuakeCoRE, AF8 [Alpine Fault magnitude 8], Canterbury Seismic Instruments (CSI), and University of Canterbury, funded by the Unlocking Curious Minds fund. QuakeKit has two parts: the installation of seismometers in schools around the Alpine Fault and an education session at each school.

During part 1, the seismometers are installed in the schools and connected to the CSI Sentinel app, which following major shaking will instantly evaluate the building's status based on measured ground shaking and the New Zealand design code, and sends alerts directly to the principal of the school along with the local Civil Defence Emergency Management (CDEM) Emergency Management Officer (EMO). The alerts immediately display potential damage to the building via a "traffic light" status.

Part 2 consists of visits to schools which participated in the 2019 AF8 Roadshow: *The Science Beneath Our Feet*. The visits include:

1. Education session about the seismometers that were installed and more information about earthquakes and the Alpine Fault.
2. An activity to build the tallest tower which is tested on a shake table and given the same "traffic light" system to note the building damage.
3. A talk from the local EMO to better understand local hazards.
4. An activity which allows the students to swing a sledgehammer onto the ground in order to measure and analyse seismic waves (via MASW testing method) at each site so engineers can better understand the stiffness of the soil and its response to ground shaking.

The overall goal is to communicate how science and technology can help communities stay safe and increase resilience following a large earthquake event. The purpose of this paper is to present the process of the education sessions aimed at improving understanding and communication of seismic hazards and risks.

1 INTRODUCTION

QuakeKit: Investigating earthquake science and technology (AF8, n.d. c) aims to inspire scientific inquiry among youth and demonstrate the relevance of science and technology in understanding and preparing for earthquakes. It builds on the activities and science shared through the AF8 Roadshow: *The Science Beneath Our Feet* (AF8, n.d. a) in 2019, offering an opportunity for students to further explore current earthquake hazard and impact science relevant to them and their region, by sharing information, tools and activities to teach and increase resilience. QuakeKit is a collaborative programme through the University of Canterbury, AF8 and Te Hiranga Rū | QuakeCoRE.

AF8 [Alpine Fault magnitude 8] is a programme of scientific modelling, response planning and community engagement designed to build collective resilience across the South Island to a future Alpine Fault earthquake.

Te Hiranga Rū | QuakeCoRE is a Centre of Research Excellence funded by the Tertiary Education Commission to address key areas of multi-disciplinary research in the field of earthquake resilience.

2 CONNECTING WITH COMMUNITIES AND INSTALLING SEISMOMETERS

2.1 Connecting with Schools and CDEM groups

The QuakeKit schools tour built upon the activities and science shared through the inaugural AF8 Roadshow in 2019. The tour visited 14 communities, including 11 schools, around the South Island to share AF8 hazard and impact science and preparedness information with communities likely to be impacted in a future Alpine Fault earthquake. Communication with the communities was initiated by AF8 and the local Emergency Management Officers (EMO).

The AF8 Roadshow itinerary was developed using the AF8 South-to-North rupture scenario (AF8, n.d. b) impact map to identify communities in higher impact areas, including at least one from each 6 South Island CDEM regions (see Figure 1).

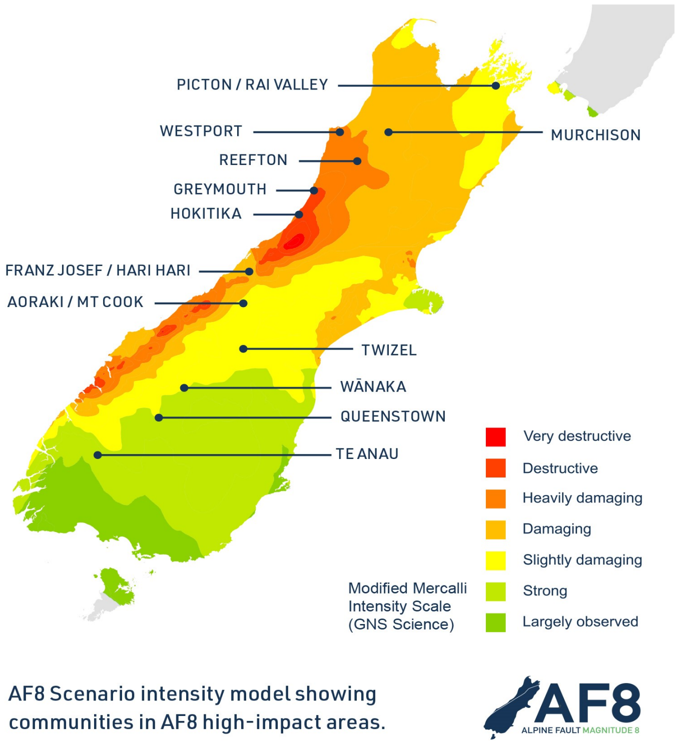

Figure 1: AF8 Scenario Intensity Model Showing Communities in AF8 High-Impact Areas

In 2020, QuakeKit (AF8, n.d. c) offered an opportunity to continue this conversation, enabling students to further explore current earthquake hazard and impact science relevant to them and their region. This opportunity to follow-up reinforced learnings, encouraged further knowledge sharing and demonstrated real-world solutions designed to increase our resilience to earthquakes in New Zealand. The programme is designed to be adaptable for all school year levels but has been primarily designed for New Zealand Curriculum Levels 4-6 – intermediate to secondary. Due to the rural and sometimes remote locations visited by the QuakeKit programme, the team opened up the sessions to a wider range to maximise audience participation. The team worked with classes as young as year 3 and as old as year 13.

2.2 Seismometer Installation and the Sentinel App

2.2.1 Installation

Each school had a Canterbury Seismic Instruments (CSI) seismometer installed in September 2020. Once each school confirmed participation in the QuakeKit programme, the team established communication between the school and CSI. CSI coordinated installation dates and went to each school before the school visits began. The installation was relatively straight-forward; each school was fitted with a seismometer and given access to the Sentinel app.

In the event of major ground shaking, the Sentinel app provides a near real time initial assessment of the potential building damage state. This enables the school principal and the local EMO to decide if the school is safe or should be immediately evacuated. This is pertinent to schools around the Alpine Fault, especially in cases where schools are used as welfare centres, by providing confirmation of children's safety following a major shake.

2.2.2 How does Sentinel work?

Sentinel directly compares ground shaking against the NZ Building Code design strength of any individual structure. This is achieved by generating, in real time, a ground response spectrum for each individual building in the Sentinel network (e.g., the schools). Unlike measures such as Mercalli Scale, or peak ground acceleration, this approach relates the shaking acceleration (its intensity) and its frequency (how rapid the shaking is), to how the structure behaves.

Based on the expected size of large earthquakes, the NZ Building Code (NZS 1170.5) defines limit state curves of shaking intensity vs. frequency. The curves are scaled based on soil type, building importance level and percentage of code. Shaking beyond the Ultimate Limit State means the building has exceeded its design capacity, with possible structural damage. Shaking below the Serviceability Limit State means the building remains fully serviceable.

In the event of shaking, the app will send an immediate notification to indicate potential building damage in a colour light system. Red for evacuate, amber for indeterminable but should be careful, and white for safe, do not evacuate. Following any major ground shaking, the Sentinel app provides a tool for immediate post-event decision making, however, a building inspection by structural engineer is necessary to access the true damage state of the building.

This three tiered alert system reflects the classification system used by structural engineers and Urban Search and Rescue to quickly assess the safety of buildings following severe ground shaking. USAR uses a 'sticker' system of white, yellow and red stickers to show if a building is safe enough to be entered. White-stickered buildings can be entered, yellow-stickered buildings have restricted access, and red-stickered buildings are unsafe to enter.

3 QUAKEKIT

After the seismometer installation, the QuakeKit team followed up with a day-long visit to each of the 11 schools that had received them. They shared the latest scientific knowledge about the Alpine Fault, explained why we have earthquakes and some of the key terminology we use to understand them. They then ran hands-on activities designed to encourage problem-solving, show how the seismometers work and share some of the science and technology used to increase our resilience to earthquakes in New Zealand.

3.1 Alpine Fault Education Talk

We cannot predict earthquakes, but we can prepare for them. Scientific research has shown that the Alpine Fault has a history of generating regular, large earthquakes. Over the last 8000 years, the Alpine Fault has ruptured 27 times, on average every 300 years (Berryman et al. 2012b). The last significant quake on the Alpine Fault was in 1717 (Berryman et al. 2012a, De Pascale et al. 2014). The next event is likely to occur within the lifetime of most of us, or our children and young people, for whom this is likely to have major short and long-term impacts.

By sharing Alpine Fault hazard and impact research, this project aims to equip the next important generation of decision makers in the Alpine Fault region with the knowledge and interest to engage with Alpine Fault science, and an understanding of what this information means for their community.

The QuakeKit Alpine Fault talk introduced students to the hazard posed and some of the potential impacts could be expected following the next Alpine Fault earthquake. Discussion of the potential negative impacts of an earthquake were balanced by reminding the students that it is these dynamic processes that formed New Zealand. An explanation of key earthquake terms (e.g., magnitude and intensity) was shared to introduce the next activity. An example of an in-class AF8 educational session is shown in Figure 2.

Figure 2: Alice Lake-Hammond explaining the Alpine Fault to Rai Valley Area School

3.2 Explaining seismometers

After the students were told about the Alpine Fault and the potential impacts, the team talked about seismometers and how they work. The CSI seismometer was connected to a screen and showed shaking in all three directions. The team described how a seismometer works and explained different terms commonly used in earthquake science and engineering, as shown in Figure 3. The concept of duration was illustrated by having the students jump once and then jump 10 times; the two different earthquake records were shown in real time on the screen. Intensity vs magnitude was demonstrated by having a student jump close to the seismometer and then having another student in the back of the room jump. Despite the similar magnitude event (i.e., the jumps released similar energy), the intensity of the shaking felt and measured by the seismometer was higher for the jump of the student closest to the instrument. The students were then asked to come up with scenarios which would change the intensity of an earthquake (e.g., floors of a building, how deep was the earthquake, how far away was the earthquake).

Figure 3: Brandy Alger showing how seismometers work to Murchison Area School

3.3 Tall Tower challenge

After the seismometer demonstration, the students were given a kit of materials and asked to construct the tallest tower which sustains as little damage as possible during a shake table test, as shown in Figure 4. The tallest tower post-shaking wins the challenge. The materials provided were skewers, 3D printed joints, and a building plate. The aim of this activity, was to allow students to think about how structures are made to resist earthquake shaking in a fun and engaging way.

After testing the students' tower on shake table, a rapid assessment is made of any damage. Following the USAR system, each tower was given a white, yellow or red sticker, depending on how it performed. A bonus 20 mm of height was added to towers that received a white sticker and red-stickered towers were disqualified.

White sticker: No obvious structural problems were observed. Any damage was minor and restricted to one or two joints. In reality, the tower would be able to be occupied, but this does not mean the tower would be completely safe.

Yellow sticker: The structural safety of the tower was questionable. There may be a few joints that have moved out of place or the tower may be on a lean. Future earthquakes may cause more damage. In reality, access would be restricted to parts of the tower only and/or would be short term.

Red sticker: The tower was seriously damaged, and would be dangerous to enter. The tower may have partially or completely collapsed. In reality, people would not be allowed to enter the tower.

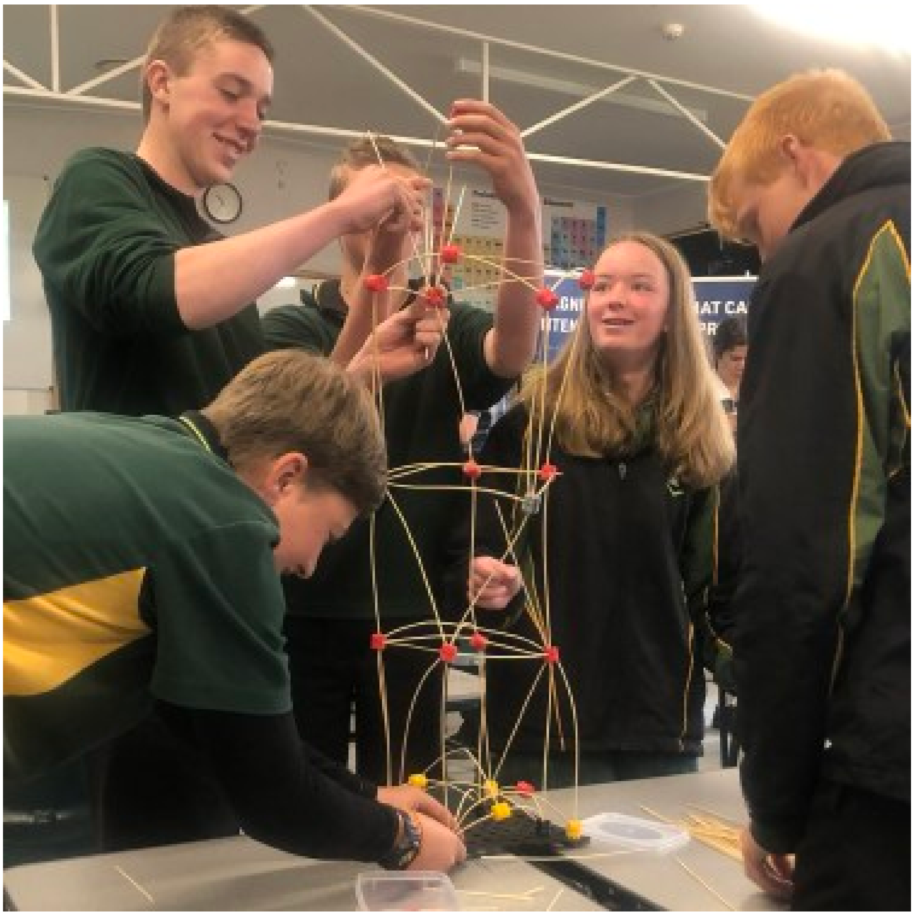

Figure 4: Students from Fiordland College building their Tall Tower

3.4 Talk from local Emergency Management Officer

QuakeKit travelled through all 6 South Island CDEM Groups and each school visit included a talk by the local Emergency Management Officer (EMO). The purpose of this was two-fold: (1) to introduce the students to the EMO and talk about the role of CDEM in their region, and (2) to have the EMO explain local hazards for that specific region, to ensure the science and technology being shared was grounded in a local context. The students listened to the EMO and then were asked which hazards are in New Zealand (e.g. bush fire, tsunami, earthquake, landslide, etc.) and which are local to their area. They were then asked what they would do in one of these situations and how prepared their family is to withstand the next hazard. The students then practiced their Drop, Cover and Hold and the EMO concluded the session with questions from the audience. According to National Emergency Management Agency (NEMA) Drop, Cover and Hold is the right action to take in an earthquake (Get Ready, n.d.). People should drop down on their hands and knees, cover their head and neck, and hold on to a shelter until the shaking stops.

3.5 Geophysical testing demonstration

The final part of the educational programme was a field demonstration of a seismic geophysical method commonly used in engineering practice and research to characterise the stiffness (i.e., shear wave velocity) of soil at each of the school sites. The multi-channel analysis of surface waves (MASW) testing method involves the excitation of seismic waves at the ground surface using sledgehammer hits on a plastic or steel strike plate (Park et al. 1999, Foti et al. 2014). The waves travel along the ground surface and are measured by a linear array of 24 vertical sensors (i.e., geophones), typically spaced 1 to 2 metres apart. The recorded waveforms are processed to develop a 1D profile of shear wave velocity with depth of the near surface (< 25 metres). An example MASW demonstration is shown in Figure 5. This testing demonstration served two purposes. First, the students were exposed to a "real-world" testing method used by engineers and geophysicists in practice. Via striking the ground with a hammer and observing the resulting waves on a computer screen, the concepts of seismic waves, magnitude, and intensity were reinforced. Students were excited to participate in the collection of the data by hitting ground with the sledgehammer. Second, the results of the testing can be used by researchers and practitioners to understand ground shaking at the site and inform decision making locally and nationwide.

Figure 5: Dr Andrew Stolte demonstrates the MASW testing method to the students at Murchison Area School

4 CONCLUSION

QuakeKit was designed to equip students and their communities with the knowledge and interest to engage in the latest earthquake science and technology, and enable communities to use this knowledge to be better prepared. Visiting 11 schools and over 750 students in 3 weeks allowed for learning and reflection about what information communities know and do not know. Many of the students were vaguely aware of major hazards, such as the Alpine Fault, but were not prepared for local hazards or aware of the various ways to increase resilience to future earthquake events. The students, teachers, and principals were highly engaged throughout the entire process and provided positive feedback. Students learned more about natural hazards, engineering, and how to better prepare for future events. Each community that was visited by the team was grateful for the opportunity. The schools were given access to the Sentinel app as well as contact details for the CSI team for any technical issues or questions. Each school was also given a set of curriculum modules which delineate the learnings of the QuakeKit visit along with more hands-on lessons directly relating to earthquakes. Pending funding, the team plans to extend QuakeKit to a new network of schools over the next couple of years.

REFERENCES

AF8. n.d. a "AF8 Roadshow 2021."Accessed March 31, 2021. https://af8.org.nz/af8-roadshow/

AF8. n.d. b "AF8 Scenario." Accessed March 31, 2021. af8.org.nz/af8-scenario/

AF8. n.d. c "QuakeKit: Investigating earthquake science and technology." Accessed March 31, 2021. https://af8.org.nz/quakekit2020/

Berryman, K.R, et al. 2012a. Late Holocene rupture history of the Alpine Fault in south Westland, New Zealand. *Bulletin of the Seismological Society of America*, 102(2): 620- 638.

Berryman, K. R., et al. 2012b. Major earthquakes occur regularly on an isolated plate boundary fault. *Science*, 336(6089): 1690-1693

De Pascale, G.P., Quigley, M.C. and Davies, T.R., 2014. Lidar reveals uniform Alpine fault offsets and bimodal plate boundary rupture behavior, New Zealand. *Geology*, 42(5), pp.411-414.

Foti, S., Lai, C.G., Rix, G.J., & Strobbia, C. 2014. Surface wave methods for near-surface site characterization. CRC press.

Get Ready. n.d. "Earthquakes." Accessed 31 March, 2021. https://getready.govt.nz/emergency/earthquakes/

New Zealand Standards. 2004. NZS 1170.5:2004 Structural design actions - Part 5: Earthquake actions - New Zealand.

Park, C.B., Miller, R.D. & Xia, J. 1999. Multichannel analysis of surface waves. *Geophysics* 64: 800-880.