The value of information on natural hazards

Unpacking the value of GeoNet

NZIER report to EQC

May 2014

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NZIER was established in 1958.

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Key points

GeoNet is a geological hazard monitoring system that includes a network of geophysical instruments, automated software applications and staff focused on earthquakes, volcanic activity, large landslides, and tsunami. The system is the result of a sustained collaboration between the Earthquake Commission (EQC) as owner and cornerstone investor, GNS Science (GNS) as steward and developer and a wider community of researchers and users. In 2009 NZIER conducted a financial analysis of GeoNet for EQC of the initial years of the operation of GeoNet in 'peace time' conditions when there were some minor but no major geo-physical hazard events. The 2009 review concluded:

"GeoNet has provided a positive return on investment for EQC (through reduction in reinsurance costs), and also for other parties with interest in academic research (GNS, universities,…), disaster preparedness (local authorities, …..) and the wider public through impacts on insurance costs and mapping technology. ... How much of this benefit is attributable to GeoNet is indeterminate, because it is difficult to separate out other factors' influence, but the full report examines this to the extent possible."

This review evaluates the value of GeoNet in 'wartime' by focusing on the major event – the Christchurch earthquake sequence and associated Port Hills rock falls along with one less severe event – the Tongariro eruption. We assessed GeoNet's contribution during these events to the six goals in the ten-year Strategic Plan[1]:

- hazard assessment information for reinsurers, infrastructure developers etc.
- information for emergency management purposes
- improvement of engineering codes and standards
- development of the geospatial infrastructure
- improving researchers' analysis
- informing and educating the public about natural hazards.

Tongariro eruption - What did we find?

In the Tongariro case we found a complex web of widespread direct and indirect use of GeoNet by a variety of users for a range of purposes before the event, immediately after, and over time. Direct immediate users included Department of Conservation (DOC), New Zealand Transport Authority (NZTA), Civil Aviation Authority (CAA) and the community of research scientists. Indirect immediate users included the commercial airlines, local authorities, transport users, tourism operators and firms potentially subject to ash fall (Genesis Energy, forest owners, Rangipo Prison etc.). In addition there is an ongoing accumulation of knowledge as the research community updates its understanding e.g. DOC's update of Volcanic Hazard Maps.

Looking phase by phase, GeoNet was instrumental in the preparedness phase as monitoring detected the increased activity that was a harbinger for the eruption. This in turn led to increased community awareness with the telephone tree being

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[1] GNS (2009) GeoNet Strategic Plan 2010-2020.

updated. When the eruption occurred, DOC, NZTA and the CAA acted swiftly on information. In the mitigation phase the Tongariro Alpine Crossing was re-routed and structures were moved and armoured.

Overall while it was not possible to quantify the benefits uniquely attributable to GeoNet (e.g. air travel continuing but with CAA diverting flights away from the area) there was clear evidence of widespread intensive direct and indirect use for a range of purposes in all the stages of the Tongariro event. GeoNet was highly influential in achieving three of GeoNet's goals: providing information for emergency management purposes; improved hazard assessment information for infrastructure management; and informing and educating the public about natural hazards. It also contributed to improving researchers' analysis.

Christchurch earthquakes and landslips - What did we find?

We found a similar complex web of direct and indirect use of GeoNet both immediately after the Christchurch earthquake sequence and over time. Direct and immediate users included:

- insurers – to commit to repair and reconstruction
- Christchurch airport – to manage the continued operation of a lifeline infrastructure in the face of repeated aftershocks
- Port of Lyttelton – for the design of lifeline infrastructures
- Engineers – improvements in engineering standards (e.g. stairwells) incorporated in the Building Code
- Ministry of Business Innovation and Employment – setting the earthquake thresholds
- Canterbury Earthquake Recovery Authority - delineation of 'red zones' and rockfall zones
- reinsurers – in pricing and ensuring capacity remained available.

Indirect users included:

- the general public – credible science based assurance (reduced output losses)
- infrastructure developers – avoided the overbuilding of the under surface network (liquefaction maps)
- overseas researchers - Japanese drilling in New Zealand
- domestic researchers – 3D mapping of ground motion.

The interview respondents often struggled to separate the information infrastructure provided by GeoNet from the wider community of practice that has grown up around GeoNet as a hub. The GeoNet along with the Natural Hazards Research Platform[2] creates a collaborative network that extends well beyond GNS and EQC to researchers in New Zealand institutions and overseas. This wider network, which GeoNet has enabled, has yielded direct but unforeseen benefits to New Zealand. For example when the Christchurch earthquake struck, New Zealand was able to access others' resources. The US National Science Foundation supplied the 'T Rex' ground-

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[2] The Platform is a network of users and researchers focused on natural hazards for more details see http://www.naturalhazards.org.nz/NHRP/About-Us

shaking machine that was useful because of the GeoNet infrastructure. The Japanese geotechnical community was mobilised quickly and left behind valuable equipment when they had to return to Japan to respond to their own earthquake.

Because of the quality of the data infrastructure New Zealand continues to be able to leverage off others' research spending. Other geological agencies are doing detailed work in New Zealand including the Japanese who are undertaking earthquake related drilling in New Zealand.

We were unable to systematically quantify the benefits from GeoNet in the Christchurch earthquake sequence. For example, EQC's reinsurers were unable to provide with/without estimates of the benefits in reinsuring pricing and or capacity that were uniquely attributable to GeoNet. However, the reinsurers did emphasise the wide range of benefits that arose from GeoNet and the improving understanding of the processes underway that it allowed.

The scale of the losses in Christchurch, the range of users and the intensity of usage suggest that the benefits from GeoNet far outweigh the costs. Just one user (SCIRT) in Christchurch suggested that the annualised saving alone would cover around 40% of the total GeoNet annual operating expenses.

Looking at the Christchurch earthquake sequence phase by phase, the data and information GeoNet data provided was:

- limited use in preparedness
- some indirect use in response phase – public confidence/sense making
- limited direct use in recovery (timing of remediation)
- extensively used indirectly in recovery (infrastructure, reinsurance)
- extensively direct used in mitigation (rockfalls and landslides, building standards, zoning)
- increased future preparedness/recovery (indirect accumulative use).

In the Christchurch sequence GeoNet was highly influential in achieving five out of the six[3] GeoNet goals: improved hazard assessment information; hazard assessment information for reinsurers, infrastructure developers; improvement of engineering codes and standards; informing and educating the public about natural hazards; and improved information for emergency management purposes.

What it might it mean?

Formally GeoNet is a project within GNS Science which employs 35 FTEs (around 10% of total GNS Science staffing). GNS Science is the steward of GeoNet on behalf of the owner - the Earthquake Commission (EQC). In practice GeoNet is much more than a GNS project which provides an information database. GeoNet is an information infrastructure plus:

- a resource pool – maintaining a logistics infrastructure
- an enabler – connector accessing key people
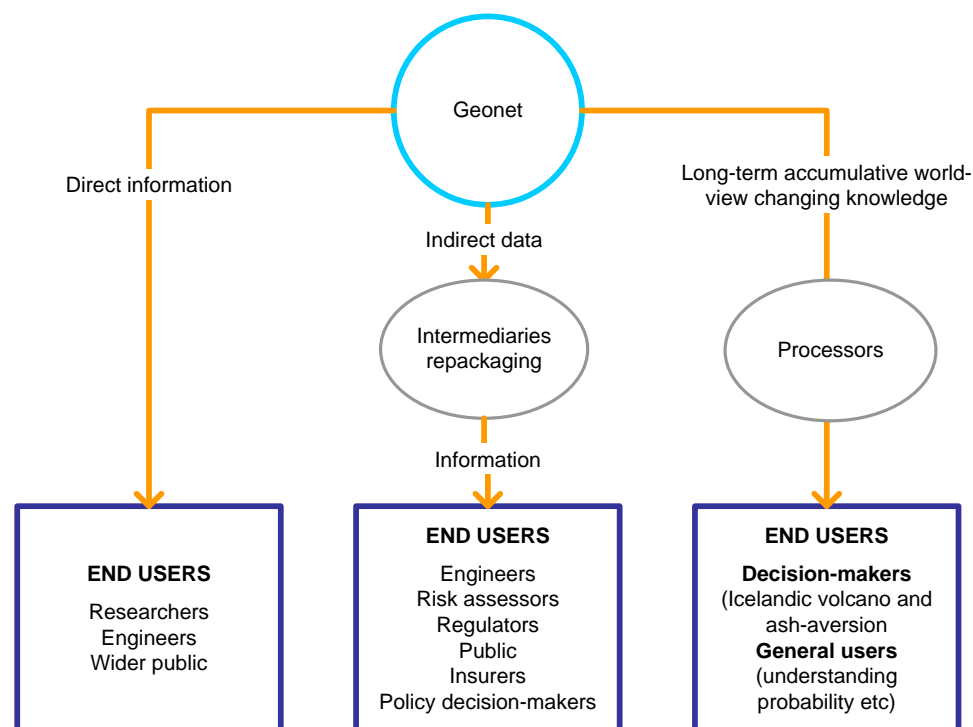- a seed funder - opening the door to key projects.

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[3] Data from Christchurch was not relevant to the sixth goal which relates to the development of the geospatial infrastructure.

The total annual cost of GeoNet consists of around $5.5m in direct operating costs, and $2.7m pa in depreciation costs. Looking across the two events these costs are limited relative to the magnitude of the benefits. In the case of Christchurch the scale of the losses, the range of users and the intensity of usage suggest that the benefits from GeoNet far outweigh the costs. The savings accruing from just two immediate uses of GeoNet Christchurch data would have been sufficient to cover the operating costs of the total national GeoNet system. This is without counting the more speculative benefits from the increased public confidence which minimised the losses in population and output (5% of Christchurch output would be worth around $800 million).

Similarly, in the case of Tongariro, a relatively small proportionate share of GeoNet resources had a large return in informing and alerting the local community, managing the closure and reopening of the major tourist attraction of the Tongariro Crossing, and in assisting in the modification of infrastructure to reduce the impacts and risks to life of future eruptions.

Figure 1 illustrates how GeoNet generates value in three ways: directly by providing information (e.g. Tongariro early warning) indirectly by providing data (used in liquefaction maps) and over time by contributing to the accumulation of knowledge (the Christchurch sequence is amongst the best recorded earthquake sequences in human history). While it was not possible to quantify the value added of GeoNet, respondents consistently emphasised the wide range of significant benefits. What this diagram doesn't capture is that GeoNet with its open data policy is now at the hub of a wider community of practice of researchers and users that extends well beyond GNS and EQC.

Figure 1 GeoNet value proposition

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1. Introduction – what was the task?

In October 2009, the NZIER provided EQC an assessment of the costs and financial benefits (CBA) of GeoNet to EQC and the wider benefits to New Zealand as a whole. The 2009 CBA was a financial analysis of GeoNet for EQC but findings highlighted the fall in reinsurance costs as GeoNet research bore fruit. It was not possible to attribute how much of the fall in reinsurance costs were due to GeoNet and how much to other factors such as the general softening in the insurance market.

The 2012 GeoNet review panel recommended (p13 2013): [4]

"That the previous Cost Benefit Analysis (CBA) be repeated by…commissioning an update of the CBA for GeoNet in particular, by looking to review the return on GeoNet in the light of the recent hazard events such as the Christchurch earthquakes, tsunami warnings[5] and volcanic eruptions".

In response to the GeoNet panel's recommendations EQC commissioned NZIER to undertake a study that focused on three Geo-Hazards – the Tongariro eruption, the Christchurch Earthquake sequence and the Port Hills rockfalls.

The primary research question in this first phase of the research was:

• For each purpose how was GeoNet data and information used?

The GeoNet strategic plan[6] identifies the range of potential stakeholders and the different purposes data and information from GeoNet can be used for. These are shown in Goals for GeoNet data and information in Figure 2 below. This report discusses how the information from GeoNet was actually used in the Tongariro eruption and the Christchurch earthquake sequence. This research informs the assessment of the value has been created by the investment to date in GeoNet.

Figure 2 Goals for GeoNet data and information

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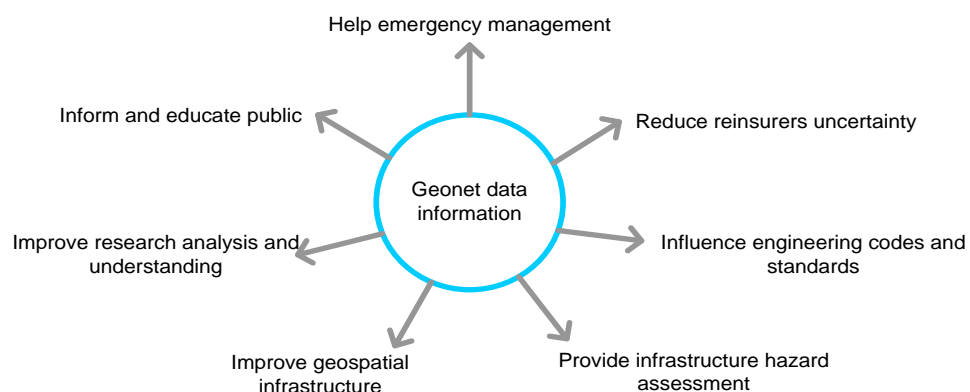
[4] GeoNet Project Panel Review (2013) Sustaining an Innovative Contribution.

[5] Phase 2 will address the recommendation from the 2013 Review (page 6) to examine' the potential returns on further investment in a tsunami early warning system for a close-in event.'

[6] GNS (2009) GeoNet Strategic Plan 2010-2020.

2. Method – what was the approach

The project involved mixed-method research involving both desk based and participant interview elements that provides a wide base of both qualitative and quantitative evidence. We proposed to examine the costs and benefits of GeoNet using one event from each domain but this approach has not proved tractable because of problems with defining the counterfactual and availability with credible quantitative estimates (which are discussed further below). Instead, we proceeded with the Tongariro eruption for volcanoes, the Christchurch earthquake and the Port Hills rockfalls and landslides as a series of short case studies (vignettes). The focus of the case studies was to define how GeoNet information was actually used by different decision makers.

We conducted a series of semi-structured interviews that focused on volcanoes (6 interviews), earthquakes (19 interviews) rockfalls and landslides (6 interviews). The volcano interviews were conducted in September 2013 and Christchurch interviews mainly occurred in October 2013. The list of key stakeholders identified by GNS and EQC who were interviewed is attached as Appendix A of this report. The interviews were organised around a set of standard questions about the respondent's role, the chronology of events, the key players, how GeoNet was used, what the impact on decision making was, what estimates were there of the value that was created, and what would have happened if GeoNet didn't exist. The focus was on eliciting

- Who uses GeoNet natural hazards information?
- For what purpose?
- To what effect?
- What value is created?
- What is the unique value added from GeoNet?

These interviews were captured in note form and analysed for patterns – the purposes GeoNet information was used for and whether usage was direct or indirect, immediate or accumulative. We also looked for but failed to find examples of where there were any adverse or unintended consequences from GeoNet.[7]

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[7] The external reviewer highlighted the risk that case studies do not take account of information not produced as resources were invested elsewhere (i.e. crowding out). However while that risk exists, the research found evidence of 'crowding in' as respondents reported that the success of GeoNet encouraged other investments in new improved Geo-hazard information to occur.

Table 1 Examples of the uses of GeoNet information

Usage	Direct	Indirect
Immediate	Decide whether to keep the airport operating	Revise the building code standards for stairwells
Delayed	Decide whether to rebuild or relocate	Build new 3D models that map ground motions

Source: NZIER

As part of the research sense-making and synthesis phase EQC convened a reference group in late February 2014 of all the key players. This workshop reviewed the initial findings from the case studies. The membership included Richard Smith & Hugh Cowan (EQC), Rob Laking (VUW), Ken Gledhill and Kelvin Berryman (GNS).

While the original research design envisaged updating the 2009 cost benefit analysis, it became apparent that no credible estimates from the benefits for the use of improved information were available[8]. For example, EQC's reinsurers were unable to provide with/without estimates of reinsurance pricing and or capacity that were uniquely attributable to GeoNet. However, they did emphasise the wide range of benefits that arose from GeoNet and the understanding of the geo-technical processes underway. As a result, we reframed the research as an outcome evaluation.

The GeoNet ten-year Strategic Plan (2009)[9] outlines six goals:

- hazard assessment information for reinsurers, infrastructure developers etc.
- information for emergency management purposes
- improvement of engineering codes and standards
- development of the geospatial infrastructure
- contributing to researchers' analysis
- informing and educating the public about natural hazards.

We have assessed the extent to which in each of the events GeoNet delivered on the goals in the Strategic Plan. The next section discusses the concepts in the literature that are used in the case studies that are presented in Section 4.

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[8] There was also the counterfactual problem: interviewees found it difficult to define what the world without GeoNet would have looked like and hence what decisions would have been made in the absence of GeoNet information.

[9] ibid.

3. Literature – what are the key concepts

The value of GeoNet substantially revolves around the worth of the improvement in the data and information it provides. The value of new information (used here to include data and knowledge) is notoriously difficult to predict or assess as its value is highly situation specific. The value of information from pure or basic research is a 'known unknown' that can range from net negative to large positive depending on the type of information and the setting. The 2009 NZIER report discussed the economics of information literature in some depth (see Section 2) and we will not repeat the detailed argument here. The key point is *"there is little by way of a general economics of information that creates an authoritative framework"* (2009 p5). Standard approaches tend to look at the value of 'known knowns'. Hazard management is about 'known unknowns' and handling discontinuous change in response to shocks.

GeoNet creates value by narrowing the uncertainty around unpredictable events and improving understanding of such events. This reduced uncertainty can improve the strategies that the public agencies, businesses, communities and individuals adopt.

Dixit and Pindyck (Investment Under Uncertainty, 1994) emphasise that given the ongoing uncertainty in the environment facing decision makers, there is an option value of waiting for better (but never complete) information. GeoNet may have reduced the option value of delaying investment decisions by providing more timely information and reducing the uncertainty surrounding the decision-making.

In order to address how decision makers actually use information about geo-hazards, it is first necessary to be clear what is meant by the terms 'use' and 'information'. In brief, information use can be direct/instrumental or indirect/conceptual. With direct use there is a direct link between information provided and decisions made. With indirect or conceptual use data, analysis or research is only one among many information sources – formal and informal, qualitative and quantitative – that decision-makers access. [10]

The improved information can be used in a variety of ways. It is important to distinguish between immediate event-contingent direct and indirect use and accumulative effects in the longer term e.g. research understanding affecting reinsurance availability/cost.

Use of information relates to the demand for and supply of information. Developments in ICT have increased the ability to collect and analyse data while costs have continued to decline. The link between the increased supply of information and the demand for this information is often assumed. However, the information supplied does not always match the needs of users for particular purposes.

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[10] There are two distinct view s in the literature on of how decision makers use information: the 'rational control model' emphases direct uses of information while the 'relativistic' perspective emphases indirect and more subjective use. In the interviews we looked for both types of usage.

Figure 3 Uses of data information and knowledge

Research interface: Direct/indirect usage
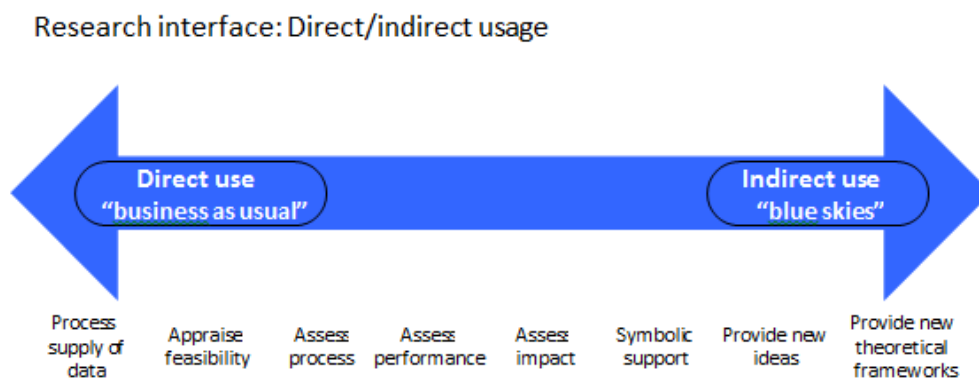
Figure 3 illustrates that usage can range from direct use in day-to-day 'business as usual' through to providing 'new blue skies frameworks' which reframe how we interpret the world. Information usage also varies in its impact – from support and legitimisation for an existing course of action through to a decisive reformulation of what is to be done.

Hazard management is generally portrayed as a cycle involving two ex ante and two ex post phases:

- mitigation - minimising the effects of disaster by reducing exposure (e.g. through planning restrictions on land use) and reducing vulnerability (e.g. building codes)

- preparedness - planning how to respond (e.g. emergency exercises/training; warning systems)

- response - efforts to minimise the harm created by a disaster (e.g. emergency relief operations)

- recovery - returning the community to normal (e.g. temporary housing).

Arguably there is a fifth learning-from-feedback phase that informs the planning for the other four phases.

While the ex post phases of the cycle overlap and the length of each phase greatly depends on the severity of the disaster, this is a useful approximation which is used in the case studies.

Patterns of information usage can vary across the different phases. Disasters are relatively rare, occur with varying degrees of warning and are the product of relatively unpredictably distributed natural hazards and more predictable exposures and vulnerabilities. The actions taken by human communities can reduce their exposure and vulnerability to natural hazards. The damage from a disaster stemming from hazard events of similar magnitude in different jurisdictions can vary widely according to the precautions and event driven actions taken by all of individuals, communities and governments to limit exposure and vulnerability.

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[11] MSD, 2001, *Improving the Knowledge Base for Social Policy: Strategic Knowledge Needs.*

Broad strategies for geo-hazard risk management fall crudely into four categories consisting of:

- avoidance
- control
- acceptance
- transfer.

Before the event greater understanding of hazard risk and potential loss can allow for more targeted risk avoidance strategies. Immediately after the event better information about what has been experienced helps assessment of risk of physical damage (should the facility be kept operating) and potential financial losses. In the recovery phase adjustment and revision of models to incorporate the latest information affects decision on risk transfer as the price and available reinsurance capacity adjusts.

Damage from hazards varies depending upon the decisions taken by individuals, communities and governments. Within each stage of the cycle there is a range of potential strategies. For example, mitigation can be achieved by avoidance, engineering or administrative controls etc. Different mitigation measures affect different decision makers.

The GeoNet Ten-Year Strategic Plan goals include a number of potential purposes GeoNet information could be used for including emergency management, improvements of engineering codes and standards, hazard assessment (e.g. for reinsurers), improving researchers' analysis, and informing and educating the public about natural hazards.

The next section explores how GeoNet information was actually used in the case studies. In the case studies we explore:

- how information from GeoNet was used by identified decision makers including Ministers, engineers, insurers, investors, emergency management personnel, and the general public
- how that usage varied depending upon the hazard management phases
- how there were different types of use - immediate event-contingent direct usage, indirect use and accumulative usage.

4. Case studies - what we found

4.1. Introduction

In a series of interviews conducted with key stakeholders over September and October 2013, we explored the different purposes that GeoNet information was used for. We have captured the results from the case studies in two vignettes. These vignettes reflect what we as researchers took out of the interviews and some supporting background material.

4.2. Volcanoes

Mount Tongariro is the northernmost of the active volcanoes in the Tongariro National Park. It has multiple craters and vents but in 2012 it had not had a significant eruption for 120 years. Although Mount Ruapehu is well monitored, following recent eruptions and the 2007 lahar event, the monitoring network on Tongariro is sparser, and local iwi have been reluctant to see more permanent equipment installed on the mountain. The Te Maari crater is also on the edge of the gazetted Te Tatau Pounamu wilderness area in the park, which is managed for minimal access and has no permanent man-made structures on the ground.

Back in 2002 GeoNet detected under Tongariro a number of low-frequency "tornillo" earthquakes, which are often a precursor to eruption. But nothing eventuated although tornillos continued sporadically until the eruptions occurred.

In May 2012 a routine annual survey of hot springs and fumeroles revealed nothing out of the ordinary, but by June a sequence of intermittent earthquake activity suggested fluids were moving below the volcano that could trigger eruption. Towards the end of July GNS convened a meeting of monitoring scientists, which resulted in the Volcanic Alert Level (VAL) being raised from zero to 1 (unrest). GNS formally notified MCDEM, the Meteorological Service Volcanic Ash Advisory Centre (VAAC), and DOC, and informally contacted local iwi, who withdrew their objection to five more monitoring stations being positioned on the mountain "temporarily" for an indefinite period. GNS also contacted researchers at Massey, Waikato and Canterbury Universities who have an interest in volcanic activity and ash impacts, and the local community took the soft precaution of updating a telephone tree of who to contact in the event of an eruption.

The VAL was maintained at 1 as earthquake activity subsided, but on 6 August the volcano's Upper Te Maari crater on its north east flank erupted in the middle of the night. It was first noticed by residents nearby who heard explosions and saw material flying through the air. They phoned DOC who contacted GNS who confirmed that instruments showed activity consistent with an eruption occurring. Some 45 minutes later DOC convened a teleconference with GNS, police, MCDEM and iwi to discuss risk management and response to the eruption. State Highways 46 and 1 were closed by police until the situation became clearer.

The Volcanic Alert Level was raised to 2[12] indicating an eruption in progress and the aviation colour code was moved to Red.[13] GNS continued to monitor seismic signals and handle enquiries from the news media through the night. First thing the following morning, a helicopter made an aerial inspection of the scene, and researchers came from Massey University in Palmerston North to collect ash samples. GNS convened another meeting of scientists and agencies to pool their various findings.

Over the next few days the weather hampered observation of the crater area, but over-flights were made to measure gas emission rates and ash was collected from the ground for analysis of composition and distribution. Monitoring showed activity and gas levels diminishing and GNS worked with DOC to assess the probability of further eruptions. Impacts of the eruption came mostly from damage to the Ketetahi Hut and track structures on the nearby Tongariro Alpine Crossing (TAC), and diversion of aircraft from airspace over the mountain. Ash-fall in the water supply of Rangipo Prison had potential to damage the pumps, and there was potential risk of damage to generators in the Tongariro Power Scheme, prompting temporary closure of the intakes. In mid-October, there was also temporary flooding on SH46 following collapse of a mud dam formed below the Te Maari crater.

The VAL returned to 1 on 17 August. By October activity appeared to have reduced sufficiently for DOC to re-open the full TAC track. But on 21 November Te Maari erupted again in the middle of the day, in view of walkers on the Crossing who took pictures and film footage and ensured global multi-media exposure of the eruption. This was however much smaller than the August 6 eruption.

Views on the value of GeoNet and associated facilities

Without GeoNet and its associated facilities, GNS and the emergency management agencies would have been more in the dark about the potential for an eruption, and GNS may not have raised the alert until later, with the possibility of agencies being in a lesser state of preparedness when the eruption occurred. GeoNet was crucial to the early detection of earthquakes that enabled GNS to put in place additional sensors that could locate activity within the mountain, and assess a high probability of eruption being in the Te Maari area. Although the actual eruption was observed before it was confirmed by GeoNet, the heightened awareness of risk and location of areas likely to be affected enabled swifter responses once the eruption occurred. The information gathered by GeoNet before, during and after the eruption also enabled time varying Volcanic Hazard Maps to be updated – more relevant than the previous average hazard maps that reflect known activity over the past 27,000 years, not all of which is still relevant to current risk – and improved risk management planning.

Value for national park risk management

DOC has principal responsibility for risk management in Tongariro National Park. A particular concern with the Te Maari eruptions was the impact on the Tongariro

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[12] Volcanic Alert Levels in New Zealand are under review, but currently denote minor eruptive activity as Level 2, significant local eruption as Level 3 (like much of the Ruapehu eruption sequence in 1995-96) and "hazardous" eruptions with greater threat to lives and property as level 4 or higher. Ruapehu in 1995-96 briefly reached Level 4.

[13] The aviation colour codes, set by the ICAO, are Green for normal; Yellow for unrest; Orange for heightened unrest; and Red for eruption imminent or in progress.

Alpine Crossing, a popular 8 hour day walk which receives 70-80,000 visitors a year, 60-80% of them from overseas. It is one of the most popular walks in New Zealand and a major draw-card for visitors to the country. It is estimated to bring $20-$80m/year of expenditure into the region, via commercial accommodation and other services.

Prior to the August eruption there was resistance to a pre-emptive closure of the TAC from local tourism interests. But the August eruption caused pyroclastic surges to impact over 300m of track and damaged 4 bunks in the nearby Ketetahi Hut. Had it happened in summer between 12 and 3pm, or on a night with people staying in the hut, multiple fatalities would likely have occurred.

GeoNet and associated warnings enabled DOC to be ready for the eruption, preparing response plans in July in consultation with iwi, forest managers and Genesis Energy. The TAC was closed immediately after the August eruption and reopened in stages: from Mangatepopo to the Emerald Lakes junction on 18 September and in its entirety on 19 October, with a Rahui imposed to 1 km around the Te Maari crater.

The November 21 eruption, when people were on the crossing, led to immediate closure of the track and its road ends. GeoNet monitoring assisted the decision to reopen the track from Mangatepopo to the Emerald Lakes on 29 November 2012. A full re-opening of the TAC, with some rerouting away from the ejection zone from the August eruption, occurred on 8 May 2013. The scientific assessment and reporting on the August eruption also assisted DOC in deciding to remove the old Ketetahi Hut and replace it with a shelter and toilet block, with caretaker's quarters armoured against medium-sized projectiles that were experienced in the earlier eruption. Warning level lights manually triggered by activity recorded on GeoNet have already been installed at the car parks at either end of the Tongariro Alpine Crossing and at the top of the Active Volcanic Hazards Zone near Blue Lake.

Value for infrastructure risk management

The biggest infrastructure impact from the eruption was the Tongariro Alpine Crossing, which was subject to closure after each eruption. Taking account of partial opening, there was no access to the track at all for 42 days after August and 8 days after November, and closure of at least part of the track for 73 and 169 days, respectively. Those closures will have reduced visitor spending in the region, although from a national perspective much of that spending will have been diverted to other parts of the country. The long term impact on visitor attraction to Tongariro is unlikely to be significant or negative: the eruptions resulted in no loss of life due to fortunate timing, and media and social network coverage of the November eruption may even have added to this destination's allure. GeoNet has still had an effect on risk reduction for the future, if not during the actual event, as new information about projectiles and pyroclastic flows has highlighted the eruption hazard for those staying overnight in that part of the mountain that led to the decommissioning of Ketetahi Hut. GeoNet data were also directly influential on the timing and location of the reopening of sections of the Tongariro Alpine Crossing.

Table 2 Disruption to Tongariro Alpine Crossing track

Days of track closure

Tongariro Alpine Crossing Track Closures after eruptions		
Days to reopening after eruptions	***6-Aug***	***21-Nov***
Mangatepopo-Emerald Lakes	42	8
Emerald Lakes-Ketetahi Road End	73	169

Source: NZIER, from information provided by Department of Conservation

These track closures do not coincide with the changes in Volcanic Alert Level. Once the volcano had stopped erupting the VAL could not remain at 2 and was lowered to 1, but there was still a risk of fresh eruption which would pose significant safety risk for those on the track with limited options to escape. As the first eruption occurred at night, the principal hazard was assessed to be from ballistic projectiles raining across the track. After the November eruption in daylight, it was apparent that pyroclastic surges were also possible, adding a second hazard to that of projectiles. Also, as there had been two eruptions it was considered there was heightened risk of further eruptions. Consequently after the November eruption the partial reopening of TAC sections furthest from Te Maari was quicker, but the full re-opening took longer, than after the August eruption.

These are consequences of the eruptions, and GeoNet's contribution rests on what would have happened without it: mostly marginal changes in costs due to greater uncertainty about re-eruption risks and increased disruption costs caused by slower response and recovery. GeoNet also contributes to avoidance of future costs to the extent that new information from the monitoring of the eruption – for instance on the type of projectiles ejected and the impact zone around the crater (from subsequent field measurements as well as GeoNet's seismic records) – enables adjustment of infrastructure (such as TAC rerouting) to reduce the event-contingent damage and disruption from future eruptions.

The other principal infrastructure imposition was from road closure, most of the costs of which were diversion costs for private vehicles. Temporary measures to protect water intakes from ash deposits at the Rangipo Prison and the Tongariro Power Scheme were short lived and inconsequential after ash-fall proved to be minor.

The value of seismic information from GeoNet comes from the better understanding it provided of the level and location of activity, which both enabled agencies and communities to be better prepared for when the eruption occurred, and assisted with the response and recovery phase in determining when track and road closures could be lifted. In the longer term it has enabled a better delineation of the high risk zones around the crater, providing more recent information to an eruption record that goes back many thousands of years. This should enable better precautionary activity in future in rerouting parts of the Tongariro Alpine Crossing track and replacing the Ketetahi hut, reducing the probability and severity of damage from future eruptions.

Value for airline risk management

The Ruapehu eruptions in 1995/96 caused much disruption to air traffic because of the volume of ash, the distribution of spread, and CAA's attempts to delimit no fly

zones on limited information. As a result of this experience GNS and CAA now have systems in place to provide information on impending risks of eruption on the ground, which is passed to airlines who make their own decisions about whether to fly. GeoNet provides data on ground-based volcanic activity which GNS passes to the MetService, who issue Volcanic Ash Advisory notices for up to 18 hours ahead. When an eruption occurs MetService also models ash plume spread (or "ash polygon") and conveys this to the Airways Corporation who distribute it to commercial airlines and airport operators.

In response to the Te Maari eruption, the presence of ash in the atmosphere created a state of "conditional airspace" which planes can still fly in given high visibility, and the controlled air-space in which commercial flights are run was lowered from 33,000 feet to 16,000 feet, enabling commercial flights to continue to fly below the ash presence. Air New Zealand cancelled a number of regional link flights to places such as Taupo and Rotorua, which use turbo-prop aircraft flying at lower levels, but continued to fly domestic jet services with minor route alteration to avoid the crater. Jetstar cancelled some of its jet services over the North Island. Airlines continued to fly across the Tasman with co-operation of the Australian authorities, and Qantas flights over New Zealand to South America continued with minimal deviation in flight path.

Since recent volcanic events (and particularly the eruption of Iceland's Eyjafjallajökull in 2010, which caused much disruption over North Atlantic and European routes, and showed up the multiplicity and lack of co-ordination and consistency of responses across different air traffic control jurisdictions) changes have been made to improve monitoring and response at international levels. Airlines are now seen as having ultimate responsibility on whether to fly or not, given reliable and timely information about ash volume (from ground sources) and spread (from meteorological modelling). Aircraft manufacturers now have better ideas about aircraft tolerance to ash plumes, and while flying through ash of $2g/m^3$ poses strong risk of engine seizure, planes losing power and crashing, ash densities of $0.002<0.004g/m^3$ are manageable in daylight hours when it is possible to see and avoid the denser cloud patches. Flying in $<0.002g/m^3$ poses little risk to flying, with minor issues for maintenance in terms of aircraft and engine abrasion. Except for the case with coarser material, ash-clouds pose more of an economic risk for airlines from increased maintenance than a safety risk for planes dropping from the sky.

The August eruption was at night when there were no passenger services in the air. A late freight flight changed its flight path from directly over the mountain. By daybreak ash advisory notices had been issued and airlines were able to route their flights around the ash polygon, using non-standard inter-city tracks with agreement from the Airways Corporation. In New Zealand airspace such deviations entail low marginal cost, provided timely information is available to reroute accordingly.

Neither the Wellington Volcanic Ash Advisory Centre (run by MetService) nor other VAACs running the same protocols model the density of ash in a plume, so it is difficult to determine the level of risk to airlines from such modelling and airways authorities tend to be conservative in seeking to shut down more air-space than strictly required for safety purposes[14]. This was a factor in claims of over-reaction to

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[14] Only the Toulouse Volcanic Ash Advisory Centre, which covers most of Europe, western Asia and Africa, has attempted to model ash densities over some of its area. The size of material fragments and clumping in space make density prediction more difficult than estimating volume ejected from ground records like GeoNet or meteorological modelling of spread.

both the Icelandic eruption in 2010 and the Chilean volcanic eruption in 2011 and which have led to aviation authorities deferring to airlines to decide what modification to make to flight plans.

The modelling from the November eruption suggested ash spread across the whole of the North Island, from Gisborne over Taupo to New Plymouth, although the size of eruption indicates this was not the case. This was a direct result of the modelling being unable to predict density, and the conservative interpretation put on Volcanic Ash Advisory notices. Diversion tracks were therefore probably wider than they needed to be. Air New Zealand has since provided more funding to the Volcanic Ash Advisory Service to improve aspects of the modelling.

Prior to August 2012, it would take the MetService 35-40 minutes to do its plume modelling and up to 90 minutes before first communications were sent to airlines. While this might be acceptable for other airlines operating jet services or international routes, Air New Zealand has a major domestic service using airways that track close to the active volcanoes, and regional turbo-prop services flying under 20,000 feet. Subsequently Air New Zealand has obtained agreement from GNS to be copied into the emails notifying MetService of an eruption taking place. In November 2012 this reduced the notification time to 21 minutes, and that notification was enough to decide on route changes for the turbo-prop services at risk.

GeoNet and volcanic risks

The role of GeoNet with respect to volcanic risk reveals both strengths and weaknesses of the current coverage. On the plus side, GeoNet is acknowledged by users for assisting preparation and response to volcanic events, and improving understanding of volcanic risks to improve investment in infrastructure to make it more resilient to future events. It has also had some unexpected benefits, for example providing a series of seismic data that was used in analysis to allay concerns about links between hydraulic fracturing in oil and gas production and earthquake generation in Taranaki: monitoring of the volcano provided the data and the experience of past seismic activity against which to compare readings caused by fracking activity. Over time a wider community of practice has grown up around GeoNet as a hub. The greater collaboration that has built up over time meant that the research effort was able to be focused after the events. It also means that the messages to the public that 'could easily get out of hand' were able to be managed and communicated effectively.

GeoNet has improved the coverage of volcanic risks in New Zealand, as now all active volcanic areas have sufficient seismic monitoring to detect emerging activity as it happens. Before GeoNet coverage was more piecemeal, with Ruapehu covered as the principal cone volcano and monitoring on one volcanic field (Auckland) and one caldera (which switched between Taupo and Okataina, depending on particular research interests at the time). Ruapehu remains the best monitored volcano because of its high recreational use and its relatively frequent eruptions, and both DOC and Ruapehu Alpine Lifts have funded upgrade of the monitoring system, and provision of a fully automated seismic and acoustic detection system that can identify eruption and trigger alert sirens on the ski field within 30 seconds.

Gas monitoring, although undertaken as a part of GeoNet, depends on monthly sampling of fumeroles on the ground or from fly-past remote sensing, so there is no

continuous real-time data series to match with seismic data. Ground based instruments for gas measurement developed by GNS have been deployed at White Island with their operation funded by GeoNet, and the same is planned to be rolled out to other locations.

Although Ruapehu has a fully automated system for raising the alert on eruptions taking place, and Tongariro now has similar capability for detecting eruptions, GeoNet-informed decisions on changing lower Volcanic Alert levels or the warning lights on the Tongariro Alpine Crossing still depend on expert interpretation and judgement calls by scientists and risk managers. Given the importance of timeliness of information (e.g. with respect to aircraft that may be operating at night) some aspects of information transmission might be speeded up by automatic messaging (as appears to be the case now for TAC warning lights).

In summary compared to the counter-factual without it, GeoNet has:

- Enabled a denser coverage of seismic sensors around active volcanic areas, building a more complete picture of activity in these areas

- Identified a pattern of activity around Tongariro that enabled additional sensors to be applied

- Enabled the location of likely activity to be pinpointed more accurately, and encouraged soft responses to improve preparedness for an eruption

- Informed responses to the eruption for timely intervention in the short term, and adjustments to infrastructure for longer term use, both of which reduce the risks to life in future compared to an alternative situation in which less is known about the hazards posed by volcanic activity.

In short, GeoNet was highly influential in achieving three of GeoNet's goals providing information for emergency management purposes, improved hazard assessment information, and informing and educating the public about natural hazards. It also contributed to improving researchers' analysis.

4.3. The Christchurch Earthquake sequence

The chronology of events surrounding the Christchurch earthquake sequence is well known to New Zealanders and needs only brief coverage. In short the sequence began on 4 September 2010 when the Canterbury region experienced an earthquake recorded as 7.1 on the Richter scale which caused significant property damage to Christchurch and the central Canterbury region, but no direct fatalities. The earthquake generated a sustained sequence of minor and major aftershocks. The largest of these was on 22 February 2011 when a magnitude 6.3 earthquake struck Christchurch killing 185 people and causing extensive property damage. Three quarters of Christchurch's housing stock (150,000 homes) suffered some material damage, 30,000 houses experienced more than $100,000 damage and around 7,500 were declared unfit for habitation

Both the major earthquakes occurred on "blind" or unknown faults, although the shake maps and other official reports had predicted moderate earthquakes in Canterbury with the likelihood of associated liquefaction.

The impact of an earthquake, and hence the risk to human life and of property damage depends upon a number of factors including location, depth, and how much energy is released. The peak ground acceleration in the February earthquake was amongst the highest ever recorded in human history and significantly exceeded the design load of the building code for a 500-year event. With two tragic exceptions where building design and construction was at fault, the direct damage was predominantly to buildings constructed before the 1970s. Most of the other property damage arose because of extensive liquefaction, but rockfalls and landslides triggered by the earthquakes (discussed below) were also a contributor.

In the response phase to the February earthquake large parts of the Christchurch CBD were cordoned off while damage to buildings and land were assessed. The closure of much of the CBD and temporary closure of a number of tertiary education providers initially significantly affected tourism, retailing and education services. However, with utilities being reconnected, manufacturing, industry and the port were able to continue operations and agriculture was not significantly affected. As a result business activity proved remarkably resilient and the fall in output from the Canterbury region and population was less than had been expected.[15]

The damage to residential housing from ground liquefaction in particular however has had a significant effect on the lives of many Christchurch residents. The prolonged recovery process is still playing out as this report is being prepared (March 2014). Survey and focus group research undertaken by Canterbury District Health Board (2013)[16] suggests:

- *"It is clear that all areas of residents' lives have been affected by the earthquakes: homes, relationships, social lives, communities, identities, finances and careers.*

- *Over eighty percent of respondents stated that their lives had changed significantly since the earthquakes.*

- *Over three quarters of respondents reported that their home was damaged and almost as many reported that their neighbourhood was damaged.*

- *Almost two thirds of respondents were grieving for the 'lost Christchurch'.*

- *The earthquakes have been seen as a 'double blow' –the earthquakes and the perceived subsequent poor management of the recovery*."

There is an element of serendipity in GeoNet's response to the initial 4 September 2010 earthquake. GeoNet already had a reasonably extensive network in place before September 2010, originally built with the intention of monitoring the effect on Christchurch of an earthquake on the great Alpine Fault.

The beginning of the earthquake sequence in September triggered a rapid network expansion as equipment intended for elsewhere was promptly deployed to Christchurch. There were significant increases in the number of urban strong motion, and structural strong motion array stations. As a result 22 February 2011 was one of the best recorded earthquakes in human history.

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[15]   See Miles Parker and Daan Steenkamp, "The Economic Impact of the Canterbury earthquakes", Reserve Bank of New Zealand: *Bulletin* 75(3) 13-25, September 2012.

[16]   Canterbury District Health Board (2013) Becoming All Right? A summary of the research behind the wellbeing campaign for Canterbury.

There were also other technological innovations in GeoNet which enhanced its usefulness. The adoption of the GFZ Potsdam software package automated and speeded up the initial earthquake location and magnitude determination. Event information was posted on the GeoNet webpage and made available to the stakeholders via mobile devices as well as through social media such as Facebook and Twitter.

"During the Canterbury earthquake sequence GeoNet became a trusted authoritative source of <Geo-hazard> information …. became a household name in New Zealand…. elevated GeoNet onto the global stage as one of the top tier data providers internationally." [17]

Like Tongariro, in Christchurch we found a complex web of direct and indirect use of GeoNet for a range of purposes. This usage occurred both immediately after the earthquake sequence and over time. The scale of the damage in Christchurch and wide range of significant users suggest that GeoNet has yielded significant benefits. Direct and immediate users (followed limited interpretation for forecast probabilities) included:

- Insurers – optimising the timing of building reconstruction
- Airport - deciding whether to keep the airport operating or close for inspection
- Port – deciding where to locate new facilities
- Building code – improvements in engineering standards (stairwells)
- Building code – used in decision-making on setting thresholds
- Mitigation - delineation of red zones and rockfall zones
- Reinsurers – whether capacity continued to be available
- Reinsurers – reducing the uncertainty premium built into pricing.

Indirect uses included:

- infrastructure – avoid overbuilding under surface networks
- public confidence and assurance – credible science based assurance minimised the output losses
- public and private decision makers - (Ministers, company directors, landlords)
- research connections - (Japanese liquefaction equipment)
- domestic researchers - 3d mapping of ground motion
- overseas researchers – Japanese drilling in New Zealand.

We were unable to systematically quantify the benefits from GeoNet. For example, EQC's reinsurers were unable to provide with/without estimates of the benefits in reinsurance pricing or capacity that were uniquely attributable to GeoNet. However, they did emphasise the wide range of benefits that arose from GeoNet and the understanding of the processes underway. In particular, GeoNet plus analysis from research scientists that it supported played a key role in maintaining the confidence of insurance markets in the basic science behind the existing earthquake models and improved understanding of stresses facing the structural components of buildings.

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[17]   GeoNet Project Panel Review (2013) P14.

Sources indicated that without the data, information and knowledge based on GeoNet, there would have been significant adverse consequences for reinsurance pricing and the availability of capacity.

While the counterfactual is unknowable what happened is known:

"Overall reinsurance capacity is now higher than ever, the overall quality of counter party security is unchanged, the immediate post loss pressure on pricing has subsided and competitive pressures are starting to be felt with some mild softening of terms and conditions." (Email correspondence from AON Benfield dated 4 November 2013)

While there was limited direct use in the response phase, there was immediate indirect use in the response phase which assisted public confidence by helping them make sense of what they were experiencing. Making extensive use of GeoNet data, GNS scientists developed a model that forecast the decay pattern in earthquake sequence. These forecasts became a key part of the public communications strategy.

The GNS staff advised that they would not have been confident to prepare and publicise their forecasts without having access to quality of data that GeoNet supplied. Council staff advised that these forecasts were important in retaining a sense of public confidence and it encouraged residents to stay in Christchurch rather than relocate elsewhere. While no estimates of the output loss avoided are available it is possible to get a sense of the order of magnitude of hypothetical gains. Christchurch accounts for about 8% of national GDP, so an avoided loss of 5% of Christchurch output would be worth around $800 million to the regional economy, although somewhat less for New Zealand at large after allowing for some production relocation to other regions.

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Box 1 – the use of science in the Port Hills rockfalls and landslides

The layers of volcanic ash, loess and boulders on the Port Hills proved very vulnerable to being destabilised by earthquakes. The February earthquake triggered a damaging set of cliff collapses, cliff top instability, rockfalls and landslides, boulder rolls. This resulted in the loss of 5 lives and significant property damage. It also raised concerns about the vulnerability of the affected areas to the risk of further loss of life and property damage.

In the post-earthquake mitigation phase GNS were commissioned to undertake a range of work that included sophisticated modelling of the potential hazards from rockfalls and landslides (see http://www.ccc.govt.nz/homeliving/civildefence/chchearthquake/porthillsgeotech/porthillsgnsreports.aspx#jumplink8). For some of the reports produced GeoNet data was crucial to this modelling as it was predicated on GNS forecasts of how the earthquake sequence would decay over time. Respondents described GNS work as 'cutting edge' and 'path-breaking'. GeoNet data and GNS forecasts were leveraged to generate risk bands such as a 1/10000 annual indirect fatality. These risk bands were used directly in decisions on which properties were to be red zoned and not available for dwellings.

Decisions on the risk zoning would likely be highly contentious and were likely to be subject to action for legal review. This is because existing dwellings were assessed as unsafe for human habitation and would have to be removed. Respondents described how the science provided a sword and a shield – a sword because it increased the difficulty of defending poor decisions, a shield because it provided a defensible rationale for the decisions that were made.

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Box 1 discusses the use of science in the Port Hills rockfalls and landslides. More generally, what the Port Hills case study brings out is a theme that ran through the aftermath of the Christchurch earthquake sequence – the active use of science in decision-making. GeoNet provided a platform of timely, credible, authoritative information freely available to all potential users. This provided the firm ground on which the scientists felt they could stand and engage in the wider public discourse. Thus science filled the vacuum left by the events of the Christchurch, a vacuum which could easily have been filled by charlatans and cranks.

The increased availability of information does not guarantee that good decisions will be made. And what is a 'good' decision will be heavily contested.[18] But improved information did increase the probability of getting evidence informed decisions and increased the difficulty of defending bad decisions. Sources indicated this was particularly important in assisting political decision makers and their advisors when decisions (such as red-zoning) were likely to be subject to reviewed.

Looking at the Christchurch earthquake sequence phase by phase, GeoNet data provided:

- limited use in preparedness
- some indirect use in the response phase – public confidence/sense making
- limited direct use in recovery (timing of remediation)
- extensive indirect use in recovery (infrastructure, reinsurance)
- extensive direct use in mitigation (Port Hills rockfalls and landslides, building standards, zoning)
- increased future preparedness/recovery (indirect accumulative use).

It was in the recovery phase that the use of GeoNet came to the fore: extensive indirect use in recovery (infrastructure,) direct use in mitigation (rockfalls and landslides see Box 1), building standards and zoning. In addition the accumulated knowledge will assist in future preparedness.

In the Christchurch sequence GeoNet was highly influential in achieving five out of the six GeoNet goals: improved hazard assessment information; hazard assessment information for reinsurers; infrastructure developers; improvement of engineering codes and standards; informing and educating the public about natural hazards and improved information for emergency management purposes.

The scale of the losses in Christchurch and range of users suggest that the benefits of GeoNet far outweigh the costs. We note that the total annual cost of GeoNet consists of around $5.5m in direct operating costs, and $2.7m pa in depreciation. By comparison just one user Stronger Christchurch Infrastructure Rebuild Team (SCIRT) from the many listed above suggests that the annualised saving alone would cover around 40% of the total GeoNet annual operating expenses.

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[18] See Tailrisk Economics Error Prone Bureaucracy Earthquake strengthening policy formulation in New Zealand 2003 13: A study in failure (2014)

5. Summary of findings and implications for future research

We undertook an outcome evaluation using the six goals in the GeoNet ten-year Strategic Plan (2009):

- hazard assessment information for reinsurers, infrastructure developers
- information for emergency management purposes
- informing and educating the public about natural hazards
- improvement of engineering codes and standards
- development of the geospatial infrastructure
- improving researchers' analysis.

In Table 3, we have summarised the extent to which GeoNet for each of the events delivered on these goals. (We have also included an estimate of the likely order of magnitude of the public value added where this was possible to judge).

Table 3 Assessing GeoNet's impact on the goals

GeoNet Goal	Tongariro	Christchurch	Comment
Hazard assessment information for reinsurers, infrastructure developers etc.	Moderate impact (new hazard maps and realignment of infrastructure) (moderate value)	High impact (confidence retained in underlying models) (high value)	GeoNet's impact was related to the severity of the event
Information for emergency management purposes	High impact (moderate value)	Low direct impact	Volcanoes have lead times, earthquakes can't currently be predicted
Informing and educating the public	High impact (moderate value)	Moderate impact (high value)	Science filled the vacuum and 'kept out the charlatans'
Improvement of engineering codes and standards	No direct impact on codes but influenced engineering practice	High impact e.g. information on the forces acting on stairwells (moderate/high value)	Improvements are related to the severity of the event
Geospatial infrastructure	NA	NA	NA
Improvement of researchers' analysis	Moderate impact (moderate potential value)	(high potential value)	GeoNet is one of the world's 'top tier data providers'

Source: NZIER

However, reviewing against the goals[19] does not fully capture the value that GeoNet adds. Formally GeoNet is a project within GNS Science which employs 35 FTEs (around 10% of total GNS Science staffing). In addition in the course of a year as many as 80 GNS Science staff may be working on the GeoNet project, mostly on a part-time basis. GNS Science is the steward of GeoNet on behalf of the owner - the Earthquake Commission (EQC).

The 2013 GeoNet review described GeoNet as *'a gem – a brilliant example of government agencies collaborating effectively together to create public value.'* GeoNet is now more than an information infrastructure. It also is a:

- resource pool – maintaining a logistics infrastructure (e.g. for responding to landslips)
- enabler – a connector joining up key people
- seed funder - opening the door to key projects (e.g. co-funding research developments).

GeoNet is now at the hub of a wider community of practice of researchers and users that extends well beyond GNS and EQC. This wider network, which GeoNet has enabled, has yielded direct but unforeseen benefits to New Zealand. For example, because of the quality of the GeoNet data infrastructure, New Zealand is able to leverage others research spending. Other geological agencies are doing detailed work in New Zealand. As one respondent observed '*New Zealand is now the global geo-hazard laboratory for the world*'.

GeoNet has also provided a model for different ways of working. Using GeoNet as an exemplar, EQC have been able to build a shared repository of Geotechnical information in which information is shared across users rather than each provider holding the information privately. In both the Tongariro and Christchurch case study GeoNet was an attractor that helped glue together a community of practice. The combined efforts of this community far exceeds what each researcher could have achieved alone.

Given this leverage is there further value added from additional investment in GeoNet or are diminishing marginal returns now setting in? What is the potential for investment in a new information source such as Tsunamis that could be included in GeoNet? More generally where are the highest returns likely from investment in EQC's Research and Education wider programme?

These wider forward looking questions will be the focus of a Stage 2 project under discussion with EQC. The next stage will review the value of EQC's research and education (R&E) programme in light of the findings in Stage 1 generally and those of the Canterbury earthquake sequence in particular. It will also respond to the recommendation in the 2013 GeoNet review (page 6) to examine "the potential returns on further investment in a tsunami early warning system for a close-in event. This stage will take a portfolio wide approach including investment in new scientific knowledge and potentially activities undertaken to improve the uptake of new knowledge by individual, community, government and private decision makers.

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[19] GeoNet Project Panel Review (2013) Box 2 P33 discusses GeoNet's partial role in developing NZ Geospatial infrastructure.

Appendix A List of people met

CERA

Jan Kupec, Geotechnical Engineer
John Scott, Manager Port Hills Project
Roger Sutton, CEO
Benesia Smith

Christchurch City Council

Peter Kingsbury, Principal Advisor, Hazards
Peter Doolin, Port Hills rockfalls

Stronger Christchurch Infrastructure Rebuild Team (SCIRT)

Duncan Gibb

University of Canterbury

Jarg Pettinga, Professor & HOD Geological Sciences
Dr Misko Cubrinovski
Dr Brendon Bradley

GNS

Dr Kelvin Berryman, Natural Hazards Research Platform
Dr Terry Webb, Acting CEO
Dr Stephen Bannister, Seismologist
Dr Matt Gerstenberger, Forecast Modeller
Dr Gill Jolly, Head of Volcanology
Dr David Johnston Joint Centre for Disaster Research

Central Government

Harry Keys, Technical Advisor, Volcanology, Department of Conservation
David Coetzee, Manager, Capability and Operations, MCDEM
John Hamilton, Director, MCDEM
Roger Fairclough, National Infrastructure Unit, The Treasury
Dr Lindy Fursman, Insurance Modelling, The Treasury
Peter Lechner, Civil Aviation Authority
Graeme Blick, Land Information New Zealand

Other

Rob Jury, Manager, Wellington Structural Engineering, BECA
Dave Brunsdon, National Engineering Lifelines Group
Richard Trevethick, Aon Benfield
Bob Fletcher, Manager, Operations Support, Air New Zealand
Chandrike Jayasundera, Senior Dispatch Co-ordinator, Jetstar
Graham Rennie, Principal Advisor Global Operations, Qantas Airways Ltd
Gary Bedford, Science Manager, Taranaki Regional Council