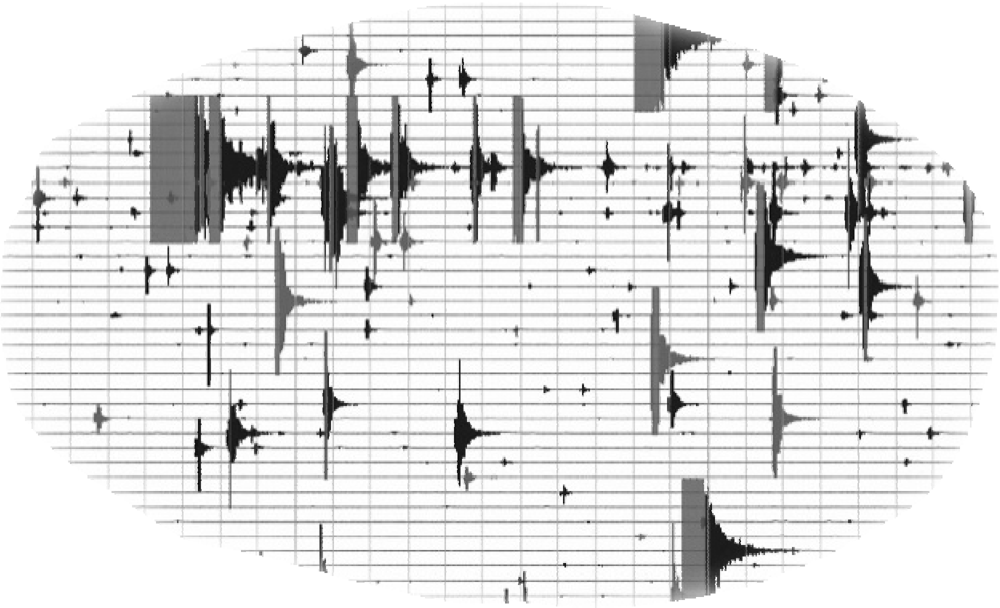
GeoNet Project Panel Review

Sustaining an Innovative Contribution



24 January 2013

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Overview and Summary

What we did

The review was centred on a two day workshop that focused on gaining the perspectives of GeoNet staff and users on recent developments and looking ahead at the possible options and developments for the future. The review team then spent time following up with management and staff from GeoNet and the EQC on issues that had emerged from the workshop.

The review team's terms of reference had six main tasks:

1. review GeoNet's fitness for purpose and development compared to the contract
2. assess the development of GeoNet since the last review in 2008
3. assess GeoNet's response to recent major events
4. review the use of GeoNet information
5. review the current funding arrangements
6. recommend directions for the future.

The next section briefly discusses our findings while the final section discusses our recommendations for future directions.

What we found

Task 1 - Review GeoNet's fitness for purpose and development compared to the contract.

The performance reporting showed that for 13 of the 14 measures 100% of service levels were achieved, with the 14th achievement at 98.1%. The panel regards this as outstanding performance for a service function. The panel were impressed by quality, coverage and level of details of the performance reporting.

Task 2 - Assess the development of GeoNet since the last review in 2008.

GeoNet has continued to mature and develop as a professional and innovative project since the previous review in 2008. For example GeoNet Rapid is a major advance on the previous manual system that has reduced earthquake location times from about 15 minutes to within 2 minutes. Special mention should be made that GeoNet Rapid was implemented during a series of major hazard events, including the Canterbury earthquakes.

Progress has occurred on multiple fronts. At the same time as increased urban strong motion monitoring capability was being developed, GeoNet has brought much of New Zealand's seismic monitoring of volcanoes up to best practice standards. The detection of unrest at Tongariro and subsequent response prior to and during the eruption is an impressive demonstration of GeoNet's and GNS Science's capabilities. Important work is also being done to provide real-time monitoring of gas emission from Ruapehu. There has been less progress on landslips, where currently GeoNet has limited equipment resources for immediate deployment. Similarly, after an initial increase in activity following the Indian Ocean tsunami of January 2004, there has been little progress with tsunami monitoring and New Zealand currently has only very limited local tsunami detection capability, and lacks a 24/7 operations centre, themes we return to below.

Task 3 - Assess GeoNet's response to recent major events.

The GeoNet project has demonstrated flexibility and adaptability to quickly modify the current work plan in response to sudden events. The project has demonstrated resilience by dealing with substantial disruptions to normal business conditions caused by the major hazard events since the 2008 review. These events include the four major Canterbury earthquakes and associated aftershock sequence, three tsunami events, and the volcanic eruptions at Tongariro and White Island. In particular the staff and management of the GeoNet project deserve much credit for responding to the needs of the stakeholders, especially the public, during the Canterbury Earthquake events, while maintaining professional standards and the "business as usual" elements of the project.

Task 4 - Review the use of GeoNet information.

GeoNet is at the forefront internationally with its policy of open access to monitoring data, contributing to its credibility as the authoritative voice on New Zealand geo-hazards. GeoNet is currently engaging with the end-users on data requirements (format, frequency, coverage) and this should continue so that key end-users can immediately integrate other geohazards information into their GIS systems.

By contrast New Zealand is well behind best international practice in development of national geospatial data infrastructure, and while that infrastructure is not GeoNet's responsibility (or that of GNS Science or the EQC), the interoperability and utility of geohazard data is reduced as a result. When the National Geospatial Data project is fully activated, staff from GNS Science and GeoNet should be fully involved in order to ensure relevant knowledge is applied to all aspects of the data specifications.

A major change since the 2008 review has been increased public profile and the increase in the use of the GeoNet website by the public with a billion hits in 2011/12. The GeoNet web delivered during the Canterbury earthquakes, but it is now time to re-focus onto the "professional" users. Access to data at the GeoNet website should be improved upon to provide the research and engineering community with a better user interface that enables improved search.

Task 5 - Review the current funding arrangements.

GNS Science and the Earthquake Commission (EQC) have worked very effectively together to develop a long-term, high trust, mutually beneficial partnership. Together in GeoNet they have created a gem – a brilliant example of government agencies collaborating effectively together to create public value.

The EQC brings the ability to commit to be a long-term funder and sponsor in order to deliver its mission of better management of natural hazard long-term risk. GNS Science brings a depth of scientific expertise and capability plus sound corporate management systems. Together in GeoNet they have created an adaptive, resilient, flexible structure which combines all the advantages of a large organisation (resilience and depth of expertise) with all the advantages of a small organisation (adaptable, responsive and flexible).

The success of the GeoNet partnership between the EQC and GNS Science has attracted other partners as 'nothing breeds success like success'. GeoNet now has a range of other funding partners such as LINZ (GPS network and tsunami monitoring), KiwiRail and Ruapehu Alpine Lifts. However, the EQC remains 'the cornerstone investor'. Forward planning has been implemented to ensure the sustainability of the presently installed equipment. However, some of the new capabilities that are discussed in the next section will require an increase in investment from wider Government and are beyond the current mandate of the EQC.

Task 6 - What is next – recommendations on future directions

Looking ahead the major challenge facing GNS Science is how to spend the available resources to best effect. This is going to require careful balancing between sustained commitment to maintenance and replacement investment while selectively investing in new or augmented capabilities. The panel has identified a number of capability enhancements. Unlike the 2008 review we did not identify a number of critical technical capabilities that are immediately required and only one immediate gap - the lack of a tsunami early warning system for a close-in event.

We have separated capability enhancements into near-term technical and managerial enhancements needed immediately in order to strengthen GeoNet's ability to respond to major events, and a set of longer-term technical and managerial opportunities to enhance the general operation of GeoNet.

Table 1: – Near-term technical and managerial enhancements required

Near-term technical enhancements	***Near-term managerial enhancements***
Earthquakes: Integrate automated moment tensor solutions for large events.	Develop a robust Media Response plan.
Adopt metadata standards, especially for site characterization of strong motion stations.	Improve the user interface for data access at the GeoNet website.
Ensure earthquake catalogue consistency following the move to GeoNet Rapid and the upgraded catalogue production.	Develop scenario response plans for high probability events.
Investigate an offshore (probably in Australia) redundant mirror system for	

GeoNet Rapid and the data archive.	
Volcanoes: At least some of the temporary deployment of instruments on Tongariro should be made permanent, and with cGPS and acoustic monitors added as required.	The equipment cache for urgent deployment during volcano unrest should include cGPS instrumentation.
More instrumentation on White Island is essential.	
Continuous monitoring of caldera lake-floor deformation should be investigated.	
More attention should be given to developing automatic alarming systems, which today exist only for Ruapehu.	
Landslide:	Review the adequacy of surge capacity in terms of both equipment and personnel to respond to a major landslide event.
Tsunami: Prioritise the improvement of forecasting tools (proposed in the Work Plan) and improve the communication of threat levels on which evacuation decisions by CDEM groups will be based. This should include easily used geospatially enabled systems and include threat maps on the website.	Investigate the possibility of partnering with government agency (such as Maritime NZ Search & Rescue) for a 24/7/365 shared operations centre. Undertake a scoping study of the options for the establishment of a local tsunami warning capability.
Data: Give priority for the development of web-based access (WMS and WFS) using open standards to allow easy discovery and availability of GeoNet data and information in geospatially enabled form for easy use by GIS and other visualisation systems.	
Governance and management:	The Cost Benefit Analysis of GeoNet should be updated to reflect the return on GeoNet in the light of the recent hazard events and augmented by an examination of the potential returns on further investment in a tsunami early warning system for a close-in event.

Looking at the set of longer-term technical and managerial opportunities to enhance the general operation of GeoNet, a number of options have been identified and these have been bolded in the report. Some of these longer-term opportunities are included for consideration as part of updates of the multi-year Work Plan to inform annual Project Work Plan and the 2015 funding review. However, others fall outside the immediate mandate of EQC and will require additional partnerships and funding resources, in some cases very significant funding resources. Looking domain by domain we have identified the following potential future opportunities:

1 Earthquakes

- Short period borehole stations for tremor monitoring.
- Consider the increased use of low-cost dense NetQuakes style stations as an alternative to CSI CUSP instruments.
- Expand the use of borehole geotechnical arrays.
- Earthquake early warning.
- Build on the existing drilling and data acquisition to expand Alpine fault zone monitoring.
- Offshore monitoring of subduction zone.

2 Volcanoes

- Consideration should be given to creating a 'virtual' designated New Zealand Volcano Observatory covering the volcano-hazard specific activities of GeoNet and GNS".
- Investigate developing MOUs with foreign volcano observatories to facilitate assistance during a major and/or prolonged volcanic crisis.
- Proposing the Taupo Zone as a GEOSS Supersite (http://supersites.earthobservations.org/) as this would improve access to satellite remote sensing data and would likely be welcomed by the international community.

3 Tsunami

- Development of protocols for communicating with MCDEM on how to utilise the increased availability of information on earthquakes to assess the potential for local tsunami.
- Support the installation of further tide gauges in selected coastal locations to enhance the LINZ-funded national network for real-time tsunami modelling.

- Investigate the establishment of a local tsunami warning capability with MCDEM and other Government agencies using the Cost Benefit Analysis (discussed under Governance and Management) as the platform for the discussion.

4 Landslide

- That GeoNet management ensure available equipment resources are both appropriate and adequate to support a rapid response to a major landslide event anywhere in NZ.
- Ensure that the national response team pool of key personnel is refreshed and the members are appropriately trained and resourced with essential equipment to provide effective and immediate field deployment.

5 Data

- Staff from GNS Science, particularly those working on GeoNet should be fully involved when the National Geospatial Data project is fully activated to ensure relevant knowledge is applied to all aspects of the data specifications.
- The capture of all data from GeoNet GPS stations should be real-time streamed and fully integrated with the LINZ PositioNZ network with the effect that the location of hazard events such as earthquakes and tsunami could be better characterised, and the network better utilised for non-hazards applications.
- Access to data at the GeoNet website should be improved upon to provide the research and engineering community with a better user interface that enables improved search capability.
- That the focus for the ongoing development effort with respect to data dissemination should be on the needs of scientific and selected business users rather than enhanced functionality for the general public.
- Investigate improving the look and feel of the GeoNet home page with links to the various instrumentation activities and new research underway.
- Investigate the use of cloud-based archive solutions and the use of these techniques to expedite the establishment of a back-up capability for earthquake and other hazards processing and archiving offshore.

6 Governance and Management

- The preparation for the 2015 funding review includes that the parties review the contract in 2013 to ensure adequate flexibilities are included. For example the contract should explicitly provide for ‘within year’ variations in the Annual Work Plan, by a process specified in the Annual Work Plan.
- That the Strategic Plan be updated to provide filters or tests that GNS Science management should use to assess proposed variations of GeoNet activity. These

filters should be applied to review and screen all planned programmes and in responding to emergent developments.

- GNS Science and the EQC need to work on succession planning to ensure that the partnership continues in the event of the departure of either of the two key senior people involved in the governance of project.

Across the set of longer-term technical and managerial opportunities to enhance the general operation of GeoNet, while some will be considered as part of updates of the multi-year Work Plan, other fall outside the immediate mandate of EQC. While progress could be made under GeoNet to scope out what is required, rolling out these new capabilities will require additional partnerships and funding resources. Growing commitments for maintenance and replacement investment limit the scope for investment in new or augmented capabilities from within the current funding envelope. In particular establishment of a local tsunami warning capability, partnering with another government agency such as (Maritime NZ Search & Rescue) for a 24/7/365 shared operations centre and enhanced capabilities in Earthquake early warning, and offshore monitoring of subduction zone, will require additional partnerships and funding resources, in most cases very significant funding resources.

Finally for this Review the process was a two-day gathering that allowed GeoNet staff and a broad range of professional uses to provide a wide range of possible options and developments for the future. The previous Review was two days of detailed presentations with GeoNet staff and a small number of selected users. The Review team believe that a more efficient outcome would be achieved by rebalancing these two generic approaches. In the future the review process should allow the Review Team more time for direct access and discussions with GeoNet staff, for example one day with a wide range of stakeholders, and one day with GeoNet staff.

Recommendations

The 2012 GeoNet review panel recommends that the EQC and GNS Science:

1. **Adopt the near-term technical and managerial enhancements identified in Table 1 in order to strengthen GeoNet's ability to respond to major events.**
2. **Review the suggested set (in 1- 6 above) of longer-term technical and managerial opportunities to enhance the general operation of GeoNet as part of the 2013/14 annual Project Work Plan and the 2015 funding review.**
3. **Investigate funding options and partners for the establishment of a local tsunami warning capability, partnering with another government agency such as (Maritime NZ Search & Rescue) for a 24/7/365 shared operations centre and enhanced capabilities in earthquake early warning, and offshore monitoring of subduction zone.**

Main Report

Introduction

The review was centred on a two-day workshop attended by around 55 participants (excluding the review panel and facilitator) from a range of backgrounds including GeoNet users, scientists, stakeholders, and staff from GeoNet and the EQC. The workshop focused on gaining the perspectives of GeoNet staff and users on recent developments and looking ahead at the possible options and developments for the future. The review team then spent time following up with management and staff from GeoNet and the EQC on issues that had emerged from the workshop.

This report captures the main findings of the review team. After the Introductory discussion which reviews the performance of the GeoNet project since the 2008 review, it is organised by domain into four parts (Earthquakes, Volcanoes, Tsunami, Landslips) with each domain including a review of current functionality, enhancements required in the near-term and then longer-term opportunities for development. Part F reviews data dissemination and standards and the final part reviews management and governance. Annex B contains the profiles of the review panel.

Part A - Review of Recent Performance

The GeoNet project has continued to mature and develop as a professional and innovative project over the period since the previous review in 2008, providing a strong foundation for the strategic goal set for this review panel: "Sustaining an Innovative Contribution".

At a high performance level, GeoNet continues the provision of hazard monitoring and data collection without cost to the end users, while meeting (mostly exceeding) the specified levels of accuracy and reliability demanded by the scientific and hazard risk management communities in New Zealand and internationally. As well as the on-going development of the collection, processing and dissemination of information to professional and scientific users, the major change since the 2008 review is the vast increase in the usage of the GeoNet website by the public with over a billion hits in 2011/12. Since the Canterbury earthquakes, the GeoNet website is the source of information for real-time hazard information for both technical users and the general public.

The review panel wish to commend the Management Group of GeoNet for their two high level planning documents:

GeoNet Strategic Plan 2010 to 2020, and

GeoNet Work Plan 2010 to 2020.

These documents provide a clear and easily understandable vision, mission and strategic goals for the 10 year period. The 10 year Work Plan details a sustainable approach for the project until 2020, with concise, easily understandable details of the projects planned. The review panel is reassured to note that planning that has been implemented to ensure the sustainability of the presently installed equipment. An intelligent and pragmatic equipment replacement and upgrade program is based on the observed reliability of both individual and groups of equipment types. More comments on the Business Plan and how it might be developed are included on page 39 under the discussion of management and governance.

The key feature of the Routine Operations and Financial sections contemplate relatively low inflation type escalation for only the salaries in the budgets, (all other categories being fixed for the first five years), while the first risk in the Risk Analysis is; "Loss of Key Staff/Expertise". This dichotomy needs to be closely watched, particularly as the panel was advised that retention and recruitment of expertise in selected areas was at times difficult.

The 2008 review panel provided advice regarding the impending completion of a new contract between the Earthquake Commission and GNS Science for the GeoNet Project. The current panel in reviewing the contract congratulates both parties for achieving a long-term 10 year contract that in the view of the panel will allow GeoNet to invest with a long-term focus in both hazard management assets for the EQC, and particularly in staff development. This will be to the benefit of both organisations.

The panel was advised that the NZIER Report (recommended in the 2008 review) was an important factor in the decision to continue the EQC funding, as it gave clear advice that the benefit to cost ratio was greater than 2, i.e. the funds EQC invested into GeoNet gave a greater than twice the GeoNet funding reduction in re-insurance costs due to better understanding of the risks from hazards in New Zealand by the re-insurers. The panel recommends that a NZIER-type study be repeated using the additional information about the benefits that GeoNet has provided to the wider New Zealand community during recent hazard events, especially the Canterbury earthquakes. While the costs of GeoNet are clear, the benefits to the wider New Zealand community, from the monitoring of the hazards and the scientific research generated, are not adequately quantified. In addition to the reassurance this will provide the board of the EQC, it will be of particular value for GeoNet regarding future investment decisions.

A key forthcoming decision for New Zealand will relate to additional investment in a sensor network and data processing equipment to alert New Zealand to local subsea earthquakes. These have the potential to create tsunami that have coastal impact travel times of minutes to a few hours, which are unlikely to be adequately detected by the current sensor networks. To be accurate and reliable, the additional investment will require increasing the number of sensors in locations close to the offshore areas that pose a high risk of tsunami-generating subsea earthquakes. This investment is a national decision and would need to involve MCDEM as the government agency responsible for tsunami warning in New Zealand as much as EQC or GNS Science. By using cost/benefit studies similar to those currently generated for transport infrastructure investments, costing both physical damage and loss of life predictions, a rational decision based on benefit can be made to invest in a hazard category that is currently making it difficult or impossible to provide adequate warnings to the majority of those at risk.

The review panel notes that the Work Plan contemplated undertaking 'business continuity' testing by exercising with the MCDEM National Exercise Program. While more detail is provided later, the performance of the GeoNet Project in responding to the major hazard events that have occurred in the period since the 2008 review would indicate that GeoNet has proved itself exceptionally well prepared to deal with substantial disruptions to normal business conditions.

The review panel was provided with the GeoNet Fourth Quarter Report 2011/12. This report contains information on the April to June 2012 quarter and the full year from July 2011 to June 2012. The report is very detailed and comprehensive. Of particular note is the overall performance summary; 13 of 14 service levels 100% achieved, with the 14^{th} achievement at 98.1%. The panel regards this as outstanding performance for a service function.

In the view of the panel the key achievement for GeoNet during the period was the response to the major hazard events during the period: the four major Canterbury earthquake events, the three tsunami events, and the volcanic eruptions at Tongariro and White Island. The management of the GeoNet Project deserves credit for responding to the needs of the stakeholders, especially the public, during these events, particularly the first two Canterbury earthquakes, while maintaining a "business as usual" approach. This is even more impressive as the development of the major initiative, GeoNet Rapid, was completed during the period. This was noted in the 2008 review panel's report as a key initiative in meeting the needs of the "emergency response" stakeholder's future requirements. To achieve a successful implementation during the 'hands on management' of a series of major hazard events such as the Canterbury Earthquakes demonstrates a mature and well-managed project.

The decision to divert investment from other areas in New Zealand, and to reinforce the seismic network in the Canterbury area following the first earthquake in September 2010, is fully supported by the Review Panel, and we believe it is fully compatible with the overall objective of the original GeoNet proposal. Discussions with GeoNet staff indicated that the decision to divert new investment into Canterbury was made within the new 2010 contract, hence demonstrating that the flexibility allowed for in the contract is operationally usable. This also reinforced the view of the panel that the relationship between GeoNet and the EQC is important to the success of GeoNet's performance. This relationship between the EQC and GeoNet is in the panel's view largely due to the excellent professional relationship between the two senior personnel, Hugh Cowan and Ken Gledhill. The panel notes that succession planning will be an important part of maintaining the future success of GeoNet.

We note substantial debate within the GeoNet team as to whether the future 'normal' investment should be to improve overall national coverage, in line with the 2000 GeoNet proposal, or to target particular regional risk areas or interesting scientific challenges. The panel believes it is unable to make useful definitive comment on this issue as we believe it is a matter for GeoNet, the EQC, and GeoNet's stakeholders to decide. We would recommend a process similar to the facilitated workshop used for this review to more widely canvas the issues, the risks and the potential trade-offs, to assist the decision process. This process should also be able to more clearly define and articulate the future strategic direction of the investment framework, which should allow for disruptive events such as have occurred over the last three years.

The 2012 review panel highly commends the GeoNet Project for performance that met the needs of both the public and the professional/scientific communities at periods of extreme pressure and stress. The innovation and professionalism shown during the February Christchurch earthquake, where bold decisions were made to provide the service the stakeholders required and staff obviously delivered at levels well beyond those expected in more normal times, have delivered impressively on the original 2000 GeoNet proposal:

"To provide an integrated monitoring system that facilitates the collection, processing and archiving of geophysical data to inform research on geological hazards and the response to major events."

The performance during these periods has easily met and well exceeds the expectations of those who proposed the creation of GeoNet in the late 1990s.

Commendations

I. **The GeoNet Fourth Quarter and Annual report. The report is very detailed and comprehensive. Of particular note is the overall performance summary; 13 of 14 service levels 100% achieved, with the 14th achievement at 98.1%. The panel regards this as outstanding performance for a service function.**

II. **The management of the GeoNet Project deserves much credit for responding to the needs of the stakeholders, especially the public, during the Canterbury earthquake events, while maintaining a 'business as usual' approach.**

III. **GeoNet Rapid is a major advance on the previous manual system that has reduced earthquake location times from about 15 minutes to below 2 minutes. That GeoNet Rapid was implemented during a series of major hazard events, including the Canterbury earthquakes, is deserving of special mention.**

Recommendations

I. **That the previous Cost Benefit Analysis (CBA) be repeated using a broader scope in order to define the benefits to include the actual benefits demonstrated in recent hazard events, especially the Canterbury earthquakes by:**

II. **The EQC and GNS Science 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 and volcanic eruptions.**

III. **The CBA should be augmented by an examination of the potential returns on further investments. A generic business case framework should be developed for future major investments (such as the near field tsunami warning system) that include the benefits from physical damage and loss of life calculations. This would enable GeoNet to diversify funding sources away from the EQC, e.g. to put together a business case for 'tsunami early warning for close-in events'.**

Part B - Earthquake Monitoring

Current functionality

Since the last review, the earthquake-monitoring component of GeoNet is making significant progress towards a fully implemented system and is actively addressing many of the critical capabilities and first-order technical enhancement recommendations made by the 2008 review panel. In particular, it is notable that this progress came during a period of multiple extreme events that significantly taxed the available staff resources.

There were significant increases in the number of regional network, urban strong motion, and structural strong motion array stations. There was a shift in the Work Plan with an increased focus on the Christchurch region, perhaps at the expense of a more distributed deployment, but as noted earlier the panel viewed this as a positive development, demonstrating the flexibility of the project team to adapt to significant events. It was the Canterbury earthquake sequence in particular where GeoNet became a trusted and authoritative resource for information and became a household name in New Zealand.

The recent adoption of the SeisComP3 software package from GFZ Potsdam has improved the initial earthquake location and magnitude determination time down to within 5 minutes for large earthquake and under 2 minutes for smaller but significant events, a level that is consistent with modern state-of-the-art networks around the world. The use of the USGS NEIC continuous waveform buffer (CWB) to provide direct access to waveform data from all seismic and tide gauge stations has helped to elevate GeoNet onto the global stage as one of the top tier data providers internationally.

In terms of data dissemination, event information is now quickly posted at the GeoNet main webpage, as well as available to the stakeholders and the public via mobile devices. In addition, two-way communication with the public is now occurring through social media links such as Facebook and Twitter. The GeoNet website also now provides complete event access to strong motion data, in a format familiar to the professional engineering community (COSMOS), via its ftp site.

The panel was very impressed with the accomplishments of the GeoNet program with respect to earthquake monitoring. This is clearly a strength and high visibility component of the overall hazards monitoring network. Given that earthquake monitoring may have been overemphasized in the last few years, and there now may be pressure to shift focus to other aspects of hazard monitoring (e.g. volcanic, tsunami), care should be exercised to ensure that the earthquake monitoring retains the level of excellence it has achieved.

Commendations

I. **Excellent progress in spite of having to respond to multiple extreme events.**
II. **Demonstrated flexibility and adaptability to quickly modify the current Work Plan in response to sudden events.**
III. **Improved location and magnitude reporting times to within 5 minutes for large earthquake and under 2 minutes for smaller but significant events.**
IV. **Increased urban strong motion monitoring capability**.

Opportunities for near-term enhancements

The response to recent significant events in all hazard areas covered by GeoNet has demonstrated the need for additional planning with respect to responding to media enquiries during these highly stressful times. The GeoNet management should examine how the various mass media outlets are handled during significant events and develop a robust plan to limit the impact on essential operational staff. It is important to provide for scheduled media access to the experts - the media expect to be able to obtain comments from them during significant hazard events – while shielding staff from excessive or uncontrolled demands. This development should include consultation that incorporates input from international colleagues at other earthquake monitoring network operation centers around the globe. GeoNet management should consider the feasibility of partnering with one or more other government agencies to establish a 24/7 operations center. The use of tools such as ShakeMap and ShakeCast to provide direct communications with government agencies and utility companies when large events occur should be implemented.

Depth estimates for earthquake locations would be improved once the work underway on an automated system by including S-wave picks is implemented within the modular SeisComP3 system. Implementing Automated Moment Tensor Solution (AMTS) software within the SeisComP3 platform would provide an improvement to magnitude determination, especially for very large events that have the potential to generate a tsunami, and where understanding the source mechanism is critical.

GeoNet has begun to adopt metadata standards for its seismic and GPS stations and the panel encourages continuation of these efforts for all data types. Metadata requirements for strong motion stations are more extensive than a regional broadband seismic monitoring network. A key component of the metadata for strong motion stations is site characterization information. It is important that efforts are made to collect this information so that the data these stations produce can be used in ground motion prediction equations for seismic hazard maps. Standards for site characterization metadata are already being developed by other networks (US-COSMOS, Europe-NERA) and could be adopted and implemented by GeoNet. In the case of structural and geotechnical monitoring arrays, more extensive layout drawings must also be included in the metadata to make these data useful to the research community.A number of participants at the stakeholder workshop expressed concern about the change in the earthquake catalogue during the switch from the old CUSP system to SeisComP3, and the lack of a single catalogue spanning the change period. It is important that the network understands how the magnitudes and locations change when switching from the old system to the new. If possible, waveforms from the period prior to the switch to SeisComP3 should be re-processed using current software to produce a single consistent catalogue. This would be a good post-doctoral or graduate student project in conjunction with operational staff at GeoNet.

Access to data at the GeoNet website should be improved upon to provide the research and engineering community with a better user interface to search through the large and increasing volume of data being generated by the system. Part F discusses in more detail how technical users should be able to request event data at a particular station, within a range of dates, such as metadata from stations within user defined coordinates.

The review panel believes that GeoNet should be prepared to take advantage of windows of opportunity as new significant events occur. These events can be used to bring in new stakeholders and partners at both the local and international level, providing new funding resources to expand on the backbone monitoring network. Response plans for high probability, significant events could be developed in advance through scenario planning that would include a list of additional resources that would be needed when such events occur.

Recommendations

Opportunities for high priority near-term improvements:

- I. **Develop a robust Media Response Plan**
- II. **Investigate partnering with other government agencies for a 24/7/365 shared operations centre**
- III. **Integrate automated moment tensor solutions for large events**
- IV. **Enhance metadata standards, especially for the collection of site characterisation data and for strong motion stations in particular**
- V. **Re-processing of pre-SeisComP3 network data for catalogue consistency**
- VI. **Improve the user interface for data access at the GeoNet website**
- VII. **Develop scenario response plans for high probability events.**

Longer-term aspirations

Looking at potential opportunities over the long-term, it's clear that additional funding resources must be obtained, so as not to impact the network's current operations. The management and scientific staff should continue to collaborate with outside agencies and academics to pursue opportunities to extend the network capabilities, leveraging the IT infrastructure that has been built through GeoNet to support the data collection activity. There were many opportunities brought forward for the future development of GeoNet monitoring at the review stakeholder workshop, some of which are presented here. A key to realising these is the need for GeoNet to actively partner with researchers and other agencies to support implementation.

The recent discovery of slow earthquakes and tremor signals in subduction zones around the world led to the discovery of these new phenomena in New Zealand using the GeoNet data. However, the higher levels of cultural and natural surface noise make it much more difficult to observe and resolve these signals at surface stations. The installation of short period borehole seismic packages at a depth of ~30-100 metres (depending on the site) would significantly reduce the surface noise and improve resolution of these phenomena.

In the event of a disaster in New Zealand that might affect the operations centre's ability to continue to provide information, a mirror system that collects the streaming data could be set up in Australia, running the SeisComP3 software, providing an emergency backup for the GeoNet enterprises. This could perhaps be combined with offsite backup storage of the GeoNet data.

Current and future advances in sensing and network technology should be tested and adopted where appropriate. Low cost MEMS sensors in low power IP based processors for data acquisition are now becoming available from multiple manufacturers and are being deployed by other networks worldwide. GeoNet should examine the data being produced by these other networks and apply these technologies where appropriate in New Zealand. While not first class observatory-style stations, these new systems do provide a low-cost way of increasing the density of strong motion observations for ShakeMap-type applications, and for observing the spatial variability of strong ground motions in the urban environment.

Given the widespread liquefaction in Christchurch, and the continued high level of seismicity in the region, the deployment of geotechnical arrays that include borehole acceleration and pore pressure data capture should be considered. This could be in collaboration with drilling for site characterization, where cased wells are left in the wake of site characterization activities at a few selected sites of interest. Once these well casings are installed they become targets of opportunity for future added-value research and instrumentation proposals, with the idea that the GeoNet network could be leveraged for managing the data being captured by these arrays.

A feasibility assessment for the development of earthquake early warning (EEW) systems represents a further development opportunity for GeoNet. It is envisaged that proposals for augmenting the existing network will be required to fully implement such a warning system, with key stakeholder investment required. Priority options for piloting such EEW systems might include at regional level an enhanced network capability to support a national infrastructure stakeholder, and at the local level with respect to a larger metropolitan area. There are now many countries that are in the process of implementing EEW and some that already have. GeoNet should collaborate with these other networks to learn from their successes and failures.

The Alpine fault zone was noted to be under-instrumented in comparison with other regions of New Zealand. GNS Science is involved in a drilling project to supporting data acquisition and archiving. Given that the probability is high for a rupture on the Alpine fault zone in the next 50 years, this could be an opportunity for a targeted near-source array (mentioned in the 2008 review panel report), and should be pursued in the long-term planning with potential for cooperation from international partners.

The 2011 Tohoku earthquake and tsunami disaster demonstrated that the lack of sensor information in the offshore region directly above the subduction zone makes the assessment of the magnitude of the tsunami quite uncertain. While the development cost in dollars is extremely high, a system that would provide the seismic and deformation observations along the Hikurangi margin trench would significantly reduce this uncertainty, and has the potential to save lives through faster and more accurate warnings of the impending tsunami. Offshore observatories are now being deployed in Japan and the United States, and GeoNet in collaboration with international researchers should investigate the options for, and costs of an appropriate observatory in New Zealand, based on the experiences of colleagues in other countries.

Recommendations

Summary of the potential future opportunities:

I. **Short period borehole stations for tremor monitoring**
II. **Australia redundant mirror system**
III. **Low-cost dense NetQuakes style stations**
IV. **Expand the use of borehole geotechnical arrays beyond Christchurch**
V. **Earthquake early warning systems**
VI. **Alpine fault zone monitoring**
VII. **Offshore monitoring of the subduction zone.**

Part C - Volcano Monitoring

Current functionality

New Zealand has a serious volcanic hazard, sited entirely on the North Island. Although the United States is much larger and has many more volcanoes, New Zealand has had more fatalities from volcanic eruptions during the relatively short written histories of the two countries. As with earthquakes, small eruptions are orders of magnitude more frequent than large ones. The consequences over this size range from restricting access to areas popular for outdoor recreation, to crippling the North Island with thousands of fatalities and a global disruption of aviation and perhaps climate. Although the probability of large eruptions is one in a thousand per year^{-1}, the recent earthquake and tsunami disaster in Japan demonstrates that even the worst case should be taken into consideration, particularly when siting lifelines and critical infrastructure.

The risk of life and property loss from eruptions is lower than that for earthquakes. Nevertheless, the benefit from monitoring is high because geophysical unrest preceding eruption can usually be detected by ground and satellite networks. In most cases, advance warnings can be made so that lives can be saved, or in other cases needless evacuations can be averted. As the primary way to reduce risk is to reduce vulnerability through evacuation, forecasts do not generally reduce property damage except for moveable assets such as aircraft and for measures to protect equipment from ash. Over the long-term, proper planning that takes into account eruption impacts can greatly reduce vulnerabilities and hence risk of property loss.

New Zealand has a modern volcano hazard program implemented by 16 GNS Science staff who contribute about 7 full time equivalent of effort to the GeoNet monitoring system. This group is highly regarded and much engaged internationally. When combined with allied New Zealand university scientists, the national volcanological capacity in both basic and applied research and in observatory operations ranks among the best in the world, rivaled only by Iceland in per capita terms.

The required suite of monitoring instruments is more diverse than in the case of earthquake hazards, because volcanism involves movement of gas and magma as well as both ductile and brittle failure of rock. Volcano disaster risk reduction involves response plans, strong ties to communities and emergency responders, and a thorough knowledge of the hazards including the eruption history and the impact of potentially active volcanoes. However, this review is confined to the monitoring component provided by GeoNet, the *sine qua non* of the operation of a volcano observatory.

To prioritise the allocation of finite GeoNet resources for volcano monitoring, GNS Science staff conducted a monitoring "gap" analysis, comparing the threat level posed by each volcano to the level of monitoring commensurate with that threat. This followed a methodology developed by the U.S. Geological Survey (Ewert et al, 2005; Moran et al,

[1] A quick count from the Smithsonian Global Volcanism list identified 11 eruptions exceeding 1 km^3 volume (much bigger than Mount St Helens) in the last 4000 years including Taranaki, Okataina (3), Taupo (two giant ones at 17 and 45 km^3, Tongariro (2), Tarawera in 1886, and Auckland

2008), but it aimed at a monitoring level a step below the USGS goal (largely not yet achieved in the US) as meeting the GeoNet standard of “fit for purpose”. By the time of this review, much of the monitoring gap has been successfully closed for seismic instrumentation, but there is a significant deficit in the number of continuous GPS (cGPS) instruments. For example, the Taranaki volcano has only one such instrument, which is of limited utility. GeoNet staff are now running deformation models to determine the desirable number of cGPS instruments for this and other volcanoes.

Since the last review in 2008, two small explosive volcanic events have occurred (White Island 2012; Tongariro 2012 – and a third at Tongariro as this report was being written), the Tongariro events being significant in that the volcano had been quiet for over a century. These were not immediately noticed at the time by the volcano observatory (a term not used in New Zealand, but widely used elsewhere) but all were recognized retrospectively in seismic and camera records.

The quick succession of hydrothermal explosions in August disrupted long-quiet Tongariro. Ballistic ejecta and lahars would likely have caused fatalities to hikers on a substantial section of the Tongariro Crossing and in the closest hut, were it not that the event occurred on a winter night when no one was present. Premonitory seismic activity and changes in fumarole chemistry had been detected, so GeoNet deployed additional seismic instruments on the volcano and provided briefings to the Department of Conservation and local people on the potential dangers. As a result local observers quickly contacted the observatory when the eruption began, which then disseminated relevant information to stakeholders and the public in minutes. The performance of the observatory should be considered a substantial success and would probably have saved many lives if the eruption had continued on to a large-scale event. This experience indicates that the expanded seismic system is much needed at Tongariro, as is the addition of acoustic sensors and an Eruption Detection System (EDS) such as exist on Ruapehu.

The other volcanic explosion occurred at night at White Island and likewise caused no injuries. Such explosions are not uncommon. The site is seismically noisy and there is only one seismometer on the island, making small events difficult to detect. Furthermore, the situation is problematic from the standpoint of risk reduction because there are no residents or infrastructure on the island and the only people at risk are tour operators, who depend on access for their livelihood, and their clients. However, casualties among tourists could have a negative impact on New Zealand’s tourist industry, not to mention being a human tragedy made more so if it were avoidable. Most tourists, even when they sign release of liability forms, assume that some official agency is monitoring adherence to safety standards. Having only one seismic station on a highly active volcano is not a credible level of monitoring for a “first world” country, and is a short step from having no monitoring at all. The volcano also threatens aviation. The volcano is not so remote from both population centres and aviation routes, so as to require the current level of monitoring to meet international practice. Much more remote volcanoes in Russia’s Kuril Islands and the United States’ Aleutian Islands are better monitored solely for the purpose of aviation safety. Four seismic instruments, and the practice should be to include cGPS, would provide the ability to locate seismic events, with some redundancy to eliminate the need to enter the danger zone during unrest.

No discussion was provided about geophysical (e.g., seismic, gravity, EM techniques) efforts to image the volcanic systems, primarily because these are not considered to be "GeoNet" activities. Evidence-based conceptual models are nevertheless important to interpreting monitoring data, focusing monitoring strategies, and developing plausible eruption scenarios.

Opportunities for near-term enhancements

As GeoNet has recognized, the activity at Tongariro and the deployment of temporary additions to the seismic network makes this an opportune time to apply for permits to make some of the new seismic stations permanent. It should be kept in mind that the explosions could represent vanguards of a new, more serious phase of eruptive activity. It is not uncommon for phreatic activity to be followed by progressively more violent phreatomagmatic and magmatic activity, so the best possible monitoring data needs to be available. In addition to detecting small earthquakes, there should be sufficient cGPS stations to detect intrusion of magma into the upper 10 km of the system. This not only provides an additional data source for early warning, it can also yield an indication of the amount of magma available should a major eruption ensue. More frequent gas sampling would also be advisable.

Important, cutting-edge work is being done to implement real-time continuous gas monitoring at the crater lake of Ruapehu. The proximity of skiers to the vent in winter makes the rapid warning of onset of activity imperative. Plans are also underway to add cGPS instruments to Taranaki. This is important because geodetic changes sometimes precede seismic activity as a harbinger of eruption. Also, the stability of the Taranaki edifice is a concern. Once unrest has begun, working on or near the cone to install additional instrumentation will become a dangerous proposition.

The fact that both the Tongariro and White Island events escaped immediate notice suggests that more attention should be devoted to automatic alarm systems. This may be problematic on White Island because of the high "background" level of activity there and the limited amount of the volcano above sea level, but will be beneficial at Tongariro and should be considered at other sites as well. Regardless of the difficulties, more instrumentation on White Island is essential.

Calderas pose a special problem because they are often restless, rarely erupt, yet produce catastrophic events. How to deal with unrest that probably will not, but could, lead to eruption is one of the outstanding problems of volcanology today. Speakers at the review meeting observed that although caldera deformation is often at a maximum in the center of calderas, these sites are occupied by lakes in the Central Volcanic Zone of the North Island. Thought should be given to installing anchored GPS monitoring buoys that can accurately measure uplift or subsidence of the lake floor. Potential objections might be overcome by including sensors of direct interest to lake stakeholders, such as measurement of pollution levels from agricultural runoff.

GeoNet quickly deployed an additional temporary seismic and GPS network stations following the identification of unrest at Tongariro, showing the value of an instrument cache for volcano emergencies. An adequate number of cGPS instruments should be added to this cache.

One issue identified by the panel was the value of creating a designated New Zealand Volcano Observatory covering volcano-hazard specific activities of GeoNet and GNS Science to facilitate international recognition of GeoNet and associated GNS Science activities devoted to mitigating eruption risk. An outsider unfamiliar with New Zealand or the World Organization of Volcano Observatories (WOVO), whether a natural hazards official or casual web-surfer, would find it easier to locate the project through such a name. Internationally, "volcano observatory" conveys the sense of an official entity that provides the authoritative word on the current state and hazards posed by a volcano or volcanoes, as opposed to the numerous more casual and less disciplined providers of volcano information for educational and scientific interest. An observatory containing authoritative up-to-date volcanic information in one place could be 'physical' or 'virtual'. However, the panel was concerned to ensure that creating an observatory would not result in the fragmentation of the integrated nature of GeoNet. If it was not possible to create a virtual 'observatory' then the disadvantages most probably outweighs the advantages.

In any case, the description of the GeoNet monitoring effort on the WOVO website is now years out of date (as are the descriptions of volcano observatories of other countries). Similarly, the volcano observatory effort, now divided between GeoNet and GNS Science websites, could be made more seamless. GeoNet needs to have its brand visible, but few stakeholders are interested in the internal structure of the organisations, they simply want up-to-date volcano information in one place.

Longer-term aspirations

The August 2012 Tongariro eruption completely consumed the time of observatory staff for two weeks. This amply illustrates that major volcanic activity will require drawing in help. The first and most obvious source is the excellent talent represented by faculty and graduate students of New Zealand universities. A third line of defense is colleagues from volcano observatories of other countries. The experience of Iceland during the prolonged Eyjafjallajokull eruption is illustrative. Because most observatories are operated by governments and out-of-country travel is often difficult for government employees, it would be desirable to develop MOUs for assistance with other national volcano hazard programs. Such assistance benefits the provider as well, because each crisis provides an invaluable learning experience. These agreements will need to be reciprocal. Regular exchanges of personnel can be used to build relationships and familiarity with procedures and the volcanoes in advance of a crisis. Further, such exchanges serve as a means to import (and export) best practices. Also along this line, the leadership role that GeoNet staff have assumed in international volcanological organizations such as Global Volcano Model (GVM) and WOVO is commendable.

GeoNet is advanced relative to many countries in making all monitoring data freely available in real time. Resistance to an open data policy, for example in the past in the United States and remaining now in a number of advanced countries, can come from possessiveness on the part of network operators (sole first access to "their" data for science and publication purposes) and fear of rogue forecasters using the data to make inflammatory public statements that undermine crisis management. The counter view is that the data were gained with public funds and therefore belong to the public. Moreover, there is much to be gained from transparency in credibility and cooperation and little to be lost through open data. Openness is a powerful antidote to conspiracy theories.

GeoNet may be able to take advantage of its open data access policy through the GEOSS program of Supersites (http://supersites.earthobservations.org/). Geological systems of internationally significant natural hazards can be proposed as Supersites if *in situ* (ground network) data from them are openly available. In return, satellite imagery that would ordinarily have to be purchased at high cost, for example Synthetic Aperture Radar (SAR) data, can be obtained rapidly and without cost. The active volcanoes of Hawaii comprise a Supersite and a similar, very strong case could be made for the Taupo Volcanic Zone (TVZ). Another path to such satellite data is the International Charter. However, this can only be invoked in a crisis, thereby potentially missing an important period of volcano unrest leading up to a crisis. . An international meeting on calderas of the Taupo Volcanic Zone (TVZ) being planned for 2014 might provide an advantageous launch point for a TVZ Supersite.

The issue of 24/7 operations (discussed in detail in Box 1 below) is important in volcano monitoring, although many observatories fall short in this regard, relying on staff with beepers and offsite checks rather than a team at a data centre full time. The aviation world is concerned about rapid detection and notification of ash eruptions and through the International Civil Aviation Organization (ICAO) has set a 5-minute warning of onset of activity as the recommended standard. Clearly this requires staff physically present at the monitoring facility. The system of Volcanic Ash Advisory Centers (VAACs), for example Wellington VAAC, operate 24/7 as part of weather services. However, VAACs rely on satellite data, which cannot provide the means for warning within 5 minutes.

I. Commendations

I. **It is recognized internationally that GNS Science with its academic partners has world-class expertise in both volcano risk mitigation and basic volcanological science.**

II. **GeoNet has brought much of New Zealand's seismic monitoring of volcanoes up to best practice standards.**

III. **The detection of unrest at Tongariro and subsequent response prior to and during the eruption is an impressive demonstration of GeoNet's and GNS Science's capabilities.**

IV. **Important work is being done to provide real-time monitoring of gas emission from Ruapehu.**

V. **The leadership role that GeoNet staff have assumed in international volcanological organizations such as Global Volcano Model (GVM) and WOVO is commendable**.

Recommendations

I. **At least some of the temporary instruments deployed on Tongariro should be made permanent with cGPS and acoustic monitors added.**

II. **More attention should be given to developing automatic alarming systems, which today exist only for Ruapehu.**

III. **More instrumentation on White Island is essential.**

IV. **Feasibility of continuous monitoring of caldera lake-floor deformation should be investigated.**

V. **The equipment cache for urgent deployment during volcano unrest should include cGPS instrumentation.**

VI. **Consideration should be given to creating a 'virtual' designated New Zealand Volcano Observatory covering the volcano-hazard specific activities of GeoNet and GNS Science.**

VII. **It would be useful to develop MOUs with foreign volcano observatories to facilitate assistance during a major and/or prolonged volcanic crisis.**

VIII. **Proposing the Taupo Zone as a GEOSS Supersite (http://supersites.earthobservations.org/) would improve access to satellite remote sensing data and would likely be welcomed by the international community.**

IX. **GeoNet should explore the possibility of partnering with other hazard agencies to develop a 24/7/365 watch office encompassing seismic, cGPS, satellite and other data streams.**

Part D - Tsunami Hazard

Current functionality

In New Zealand, self-evacuation in response to the potential threat of a local tsunami currently relies on communities responding to a felt earthquake accompanied by strong or long lasting ground shaking. This is a globally accepted approach to tsunami evacuation. With such an approach, false evacuations are a real threat to this as an effective hazard mitigation option. Communities and/or individuals may decide not to evacuate at the time of an actual tsunami. In addition, without an official tsunami threat cancellation, people cannot have any confidence about when they should return to their homes or workplace. Given these factors, the importance of establishing a robust and reliable local tsunami warning system is clear.

In the case of far-field tsunami there will be no felt earthquake to trigger self-evacuation. Instead, communities will be dependent on official tsunami warnings being issued, with sufficient lead time to effect a successful evacuation. New Zealand is a participant nation in the Pacific Tsunami Warning and Mitigation System (PTWS), a part of the Intergovernmental Oceanographic Commission of the UNESCO. The operational centre of PTWS, the Pacific Tsunami Warning Centre (PTWC) is based in Hawaii and operated by the US National Oceanic and Atmospheric Administration (NOAA). Through this centre, far-field warnings are effectively provided to the appropriate authorities of Pacific Rim nations. New Zealand tsunami forecast models can then be effectively used to predict the tsunami threat around coastal regions. A recent example of a successful tsunami impact prediction is the warnings issued following the great earthquake offshore from Japan on 11 March 2011.

At the present time GeoNet does not act as a tsunami warning centre, but provides advice to the Ministry of Civil Defence and Emergency Management (MCDEM), the New Zealand agency responsible for issuing official tsunami warnings.

Opportunities for future enhancements

New Zealand currently has only very limited local offshore tsunami detection capability, with the GeoNet instrument network deployment as yet not able to provide timely and reliable local tsunami early warnings. Several key components are required for a robust local warning capability, including:

- Improved offshore earthquake location capability. The geographically elongated and narrow form of the New Zealand landmass means that earthquake location and depth estimation accuracy drops off quickly for offshore events
- Improved earthquake size (magnitude) estimation (using both seismic and GPS techniques)
- Fast earthquake source characterisation (Moment Tensor)
- Tsunami (slow source) earthquake identification capability
- An enhanced tsunami gauge (sea level) network.

In addition to the LINZ funded 17 station tsunami gauge network, further capabilities are being researched or under development but are not immediately available. One gap concerns the lack of coverage of the West Coast of both islands where capabilities are limited to warnings based only on earthquake characteristics. Another concerns the lack of offshore capability on the east coast. Even with all the capabilities currently under development in place and functionally integrated, the addition of at least two offshore DART Buoys would also be required[2].

A further requirement for an effective local tsunami early warning system is a fully staffed 24/7 operations centre. Automation should be employed as much as possible, but with current levels of technology all countries attempting local tsunami early warnings have 24/7 staffed operations centres. Box 1 discusses the need to investigate the possibility of partnering with Maritime NZ's Search & Rescue (or another government agency) for 24/7 shared operations centre that focuses on all natural hazards including tsunami.

Box 1 – Need for a 24/7/365 operations centre

The issue of 24/7 operations centre has emerged in the discussion of earthquakes, volcanoes and in particular for tsunamis in this report. In the case of earthquakes much progress has been made in automation. In the case of volcanoes ICAO recommends, but does not require, a 5 minute warning period. Achieving the 5 minutes standard requires staff physically present in a facility rather than relying on staff with beepers and offsite checks. While automation and better systems can over time to continue to improve earthquake and volcano monitoring, local tsunami warning MUST have a 24/7 operations centre to operate effectively.

This is a 'whole of government issue' that would require a substantial investment in capability and as such relates more to the mandate of MCDEM than that of the EQC. Nonetheless there a number of whole of government options which will reduce the additional costs of such a capability. A number of government agencies already operate 24/7 operations centres including Police, the Fire Service, NZDF's Maritime Co-ordination Centre and Maritime NZ Search & Rescue. While more detailed investigation would be required, on first review Maritime NZ's Search & Rescue facility would appear to offer the best fit as it is has the peak capacity without the steady baseload of the other centres.

Ultimately, a mature natural hazards monitoring system needs a 24/7 "watch office". Not only are human eyes then immediately available, but automatic alarms can be set at more sensitive levels because a higher rate of false alarms can be tolerated than is the case for off-site, on-call experts. Such a centre can also provide important backup from a calmer location for GeoNet staff in the field responding to a crisis. This is a costly proposition, but might be accomplished through monitoring multiple hazards and partnering with other agencies. It is suggested that such a centre be incorporated into the long-term plans of GeoNet.

[2] Access to the international DART Buoy network is available via a website of the National Data Buoy Centre of NOAA and real time data transmission occurs via the Global Telecommunication System (GTS) managed by the World Meteorological Organization (WMO). This data needs to be transferred to GNS Science,

It is important to note that the GeoNet capability, even when fully developed, will only provide a small part of what is required for a robust, sustainable, end-to-end local tsunami early warning system. The warning messages need to reach the communities at risk and these communities must have pre-planned response procedures if effective local tsunami warning is to succeed and remain sustainable for decades. Additionally, it is important that any warning system not undermine self-evacuation triggered by natural warnings (strong or long ground shaking, strange sea behaviour or noise, etc.). Education is a cornerstone of sustained tsunami risk awareness and response. **The panel recommends investigation of the establishment of a local tsunami warning capability with MCDEM and other Government agencies using the Cost Benefit Analysis (discussed under Governance and Management) as the platform for the discussion.**

The recent development of GeoNet Rapid utilizing SeisComP3 software has greatly enhanced the ability to achieve a quick (1-2 minute) and accurate estimation of earthquake location and magnitude. We believe that this provides one component of a range of methodologies needed for GeoNet to contribute to an effective local tsunami early warning system. The ability to acquire a quick estimate of the earthquake hypocentre and magnitude with a high degree of accuracy and reliability will need to be matched by a fully resourced and tested tsunami simulation database; only then will early estimation of a potential local tsunami threat become possible.

The panel considers that in the medium- to longer-term the establishment of a local tsunami warning capability is important for a safer, more resilient New Zealand. The current and continually developing GeoNet capability, in terms of the rapid acquisition and availability of a range of earthquake-related parameters, will provide improved capability in terms of assessing the potential for local tsunami occurrence. How such information can be effectively conveyed and rapidly used by MCDEM will require excellent communication with agreed and established protocols.

We note that the GeoNet Work Plan 2010-2020 (section 4.3.7 Improved Tsunami Detection and Modelling Tools) also mentions that

> *"GeoNet developments will include forecasting tools to provide threat levels on which evacuation decisions by CDEM groups will be based"*

and that

> *"these tools will be fully implemented by 2011, but it is likely that major new developments in the modelling of tsunami impacts will be available and implemented by 2015."*

These targets are reasonable when we consider the role of GeoNet in the context of its contribution to assist emergency management agencies planning in order to prepare for and activate effective disaster responses.

In addition to the utilization of GeoNet seismic data in the development of a local tsunami warning system, it **is also recommended that consideration be given to enhancing the LINZ-funded national network of tide gauges also**. Real-time tsunami observation data is very important not only for the verification of the issued tsunami threat levels, but also for an appropriate robust cancellation of tsunami threat for each region.

Currently the LINZ funded tsunami gauges are calibrated to provide warning of an impending hazard. **The Review Panel recommend developing a management plan to improve the accuracy of the gauge data to provide scientific quality data.**

Commendations

- **I. The recent developments in automating estimation of earthquake location and magnitude that will assist in the more timely and accurate assessment of local tsunami risk.**
- **II. The development of forecasting tools to provide threat levels on which evacuation decisions by CDEM groups will be based.**

Recommendations

- **I. Prioritise the completion of the forecasting tools and improve the communication of threat levels on which evacuation decisions by CDEM groups will be based. This should include easily used geospatially enabled systems and include threat maps on the website.**
- **II. Investigate the possibility of partnering with government agency (such as Maritime NZ Search & Rescue) for a 24/7/365 shared operations centre.**
- **III. Development of protocols for communicating with MCDEM on how to utilise the increased availability of information on earthquakes to assess the potential for local tsunami.**
- **IV. Development of a management plan to improve the accuracy of the gauge data to provide scientific quality data.**
- **V. Consideration be given to enhancing the LINZ-funded national network of tide gauges.**
- **VI. Investigate the establishment of a local tsunami warning capability with MCDEM and other Government agencies using the Cost Benefit Analysis (discussed under Governance and Management) as the platform for the discussion.**

Part E - Landslide Hazard

Current functionality

The EQC and GeoNet provide financial support on an as needed basis at short notice, typically within 12-24 hours, in order to mobilize small expert advisory teams in the event of a significant landslide occurrence. Over the preceding few years this has occurred on eight occasions. The GeoNet Director and GNS Science geohazards management then make a recommendation on best expert team members, and the immediate response teams are typically drawn from across multiple institutions and organizations to provide best expert advisory capacity. In order to sustain this it is important that the national response team pool of key personnel is refreshed and the members are appropriately trained and resourced with essential equipment to provide effective and immediate field deployment.

Currently GeoNet has a limited equipment resource for immediate deployment. Monitoring typically requires weeks to months or perhaps longer, and may draw on significant staff resources to sustain field data acquisition and processing. Expert advisors continue in their role with oversight and provide support and advice typically to local or regional government organizations that would be expected to continue with day to day monitoring and provide equipment maintenance.

Longer-term aspirations

While many situations arise where site specific landslides are (re-) mobilized, and work is underway in both GNS Science and NIWA, to date no substantive progress has been achieved in terms of landslide forecasting based on meteorological events. Historically, high-intensity rainstorms triggering extensive shallow soil slope failures are a relatively frequent occurrence in New Zealand, especially along regions of east coast North and South Islands. If work under way in GNS Science and NIWA enable research–based methodologies to be developed and used to provide threshold rainfall intensities and levels than it may become feasible to provide regional landslide forecasts.

While further site-specific monitoring of selected landslides is technically an option, GeoNet does not have the staffing resources to support such activities over extended periods. The panel considered this in terms of national need and concluded that site-specific monitoring (for example possible ongoing rock slope instability in the Manawatu Gorge) is best placed with key site stakeholder organizations (e.g. NZTA), with that organisation able to determine if 24/7 monitoring of the instability is desirable and carries significant life-safety and cost-benefit options. In such examples the national telemetry network is available through GeoNet to provide viable real-time remote monitoring options for many parts of the country.

Landslides locally may impact on key national infrastructure such as pipeline and HT electricity corridors, as well as national, regional and district roads and rail links. Establishing real-time monitoring at specified localities is not considered a financially viable option, yet disruption of key network systems can lead to significant economic impacts. Medium-term (weeks to months) monitoring using satellite–based technologies such as differential InSAR may be effective in identifying areas involved in early stage slope instability. While the methodologies are now well established, GeoNet does not currently have the staffing funding resources to acquire the satellite imagery data and undertake the data processing and interpretation. This has been an area where recruitment has been difficult, but GNS Science now have the staff in place so this aspect of GeoNet activity should be reconsidered.

Recommendations

I. **That GeoNet management ensures available equipment resources are both appropriate and adequate to support a rapid response in the event of a major landslide event anywhere in NZ.**

II. **Ensure that the national response team pool of key personnel is refreshed and the members are appropriately trained and resourced with essential equipment to provide effective and immediate field deployment.**

Part F – Geospatial Data Standards and Data Dissemination

GeoNet geospatial data

GeoNet acquires and provides geospatial data, as defined in the NZ Geospatial Strategy (2007), as follows:

> *"… information relating to the location and names of features beneath, on, or above the surface of the Earth."*

The GeoNet data encompass raw sensor data from the monitoring network as well as layer data (digital maps) relating to geohazards.

The seismic monitoring stations and array networks operated by GeoNet provide and archive data for end-users at no cost and for immediate as well as long-term access and use via their website. The data are structured and stored within a number of nationally significant databases which include the Earthquake Catalogues. Overview maps of the event locations are being additionally provided as raster data (e.g. jpgs) and GPS-referenced point data to immediately and continuously inform end-users about earthquake events, volcanic activity, and tsunami and landslide occurrence. GeoNet operates a continuous Global Navigation Satellite System (GNSS) network of 180 stations, 36 of which are funded by Land Information New Zealand (LINZ). About 40 of these are configured to provide real-time streamed and processed data, which is provided to the national GPS network under the governance of LINZ. **In the medium to long-term consideration should be given to the capture of all GPS station data in real-time**, thus greatly enhancing the national GPS network, with clear benefits also in terms of the enhanced monitoring capability provided through the GeoNet Project. LINZ has indicated strong support for this enhanced capability although their willingness to pay all or part of the costs has yet to be tested.

In order to respond to the data user's needs GeoNet is engaging with key stakeholders to tailor preferred format and availability requirements. GeoNet is providing data in order to conform to the internationally accepted standard Open Geospatial Consortium (OGC) Web Feature Service Interface Standard (WFS) and Web Map Services (WMS) as beta-versions. Depending on end-user needs the GeoNet systems development team is further planning to transfer other spatial geohazard information, such as tsunami and volcanic events, via WMS and WFS, so that key end-users can immediately integrate the information into their GIS systems and develop priority visualization outputs. **The review panel endorses this initiative, and recommends that it be included in the short-term priorities for GeoNet**.

Starting in 2006 GeoNet has also developed an innovative way to provide for near-real-time public input into the network data. Anyone logging onto the GeoNet website can enter data as part of an earthquake "felt report". GeoNet automatically generates a map layer from this information for each event, so providing an approximate indication of the earthquake shaking intensity distribution which in turn may be used to guide rapid assessment of likely damage scenarios in affected regions.

As discussed earlier in this report, GeoNet staff are currently developing an adaptation of the USGS Shakemap application, which will allow for “felt reports” to be combined with instrumentally measured data. Once this real-time web-based application becomes available it will be an especially useful visual tool for all end-users, including members of the public. **The panel strongly endorses this development and recommends implementation in the short-term.**

In discussion with GeoNet staff the review panel was impressed by the clear focus on establishing and conforming to international best practice in terms of data acquisition, presentation, data archiving and standardisation. It is clear that the GeoNet team is striving to achieve continual improvement. Accordingly, the GeoNet project is well positioned to take full advantage of development opportunities as these arise, and is also well placed to leverage advantage from international collaborations in order to develop system capability and efficiency.

The review panel note that the primary GeoNet Rapid site is operating at a cloud provider in Auckland, and the GeoNet team is actively using cloud-based services to speed up development of key initiatives. GeoNet has kept up with international best practice to utilise cost-effective information technology solutions in order to protect its data holdings. It has also adopted technologies that allow it to manage the build and configuration of its servers in a scalable fashion. This work has been greatly facilitated by the use of cloud services in New Zealand and overseas, lessening the reliance on in-house staff and infrastructure. **The review panel endorses this approach and encourages the GeoNet team to investigate the use of cloud-based archive solutions and the use of these techniques to expedite the establishment of a back up capability for earthquake processing and archiving offshore**.

GeoNet integration into the National Spatial Data Infrastructure (NSDI)

Until recently New Zealand’s geospatial information has been developed independently by various agencies. For example Land Information New Zealand (LINZ) the lead agency on Geospatial data, currently captures geodetic data but does not collect geoscience data on geohazards generated by GeoNet.

The National Geospatial Data Strategy for New Zealand (2007) sets out the future data infrastructure for all spatial data of NZ including geoscience data. LINZ is coordinating the development of that strategy but full implementation has yet to begin. This strategy is similar to the EU European Directive in that it aims to include all geoscience related data (i.e. all geological, geohazard, soils and mineral/energy resources). As a result all GeoNet data will of necessity be included under the National Geospatial Data Strategy. Existing initiatives such as INSPIRE (an EU Directive to building a Europe-wide Spatial Data Infrastructure) as well as the Western Australian Land Information System initiative are also underway and should be used to inform the approach developed in New Zealand.

While full implementation has as yet not begun, the GeoNet team is aware of the implications of this national strategy for GeoNet's operations. **The review panel recommends that when the National Geospatial Data project is fully activated, the relevant staff from GNS Science and GeoNet should be fully involved in order to ensure relevant knowledge is applied to all aspects of the data specifications**. This is essential and must be continued and intensified.

Box 2 – Need for a National Spatial Data Infrastructure

While not central to this review of GeoNet, the panel noted that New Zealand is well behind leading international practice on geospatial data infrastructure. For example there is no easily accessible geospatial metadata service providing ready discoverability of geospatial datasets through using the standard OGC conformal catalogue services. This risks leading to duplication of information, fragmentation of effort and inconsistencies among data, systems, standards and processes and the inability to combine geospatial information to help address the issues of the day. This lack of consistency is caused by factors such as proprietary data and systems technology not allowing complete interoperability, little standardisation of maintenance procedures and the lack of agreed and available, standards for facilitating geospatial interoperability.

Greater data integration through a National Spatial Data Infrastructure (NSDI) offers the opportunity to easier access and comparability of spatial information of numerous fields, as it is accomplished by the European Union, where the European Spatial Data Infrastructure is being built with a process to integrate data from 34 themes including both physical characteristics such as topography, natural risk zones and minerals as well as human themes such as population, and industrial production.

A thematic NSDI and portal, that combines not only topographic data (as LINZ does), but also thematic data in an interoperable way, would present many advantages: it would facilitate the analysis, combination and allow further processing of relevant data for research, universities, local governments, businesses and citizens. GeoNet already has an open data policy that makes raw data available. Within an NSDI this data would be even more visible, accessible, downloadable and useable.

Components of an NSDI (such as INSPIRE) would encompass:

- A common metadata structure, e.g. according OGC conformal catalogue services
- Interoperability of spatial data sets and services, through a common (Unified Model Language) data model for all themes (based e.g. on ISO 19100 standards)
- Common network services (discovery, view, download, transformation, invoke, made available through an common NZ portal)
- Policies for data access, rights and services
- Coordination by an agreed institution.

While we recognize that specific geohazard data capture has not been central to these integrated geospatial data projects, there is a special need for such data to be captured as part of the New Zealand national database. We note the excellent contribution that the GeoNet project can make both in terms of design as well as data provision and application.

Commendations

I. **GeoNet is engaging with the customers on data requirements including format, frequency of up-date, and transmission, and reviewing whether to include spatial information on other geohazards such as tsunami and volcanic events, so that key end-users can immediately integrate other geohazards information into their GIS systems and develop priority visualization outputs.**

II. **The (2007) National Geospatial Data Strategy for New Zealand, developed by LINZ, represents a useful move towards a national spatial data infrastructure. While specific geohazard data capture has not been central to these integrated geospatial data projects, the GeoNet team is aware of the implications of this national strategy for GeoNet's operations.**

Recommendations

I. **That when the National Geospatial Data project is fully activated, the relevant staff from GNS Science and GeoNet should be fully involved in order to ensure relevant knowledge is applied to all aspects of the data specifications.**

II. **In the short-term priority be given to enabling the transfer of spatial geohazard information so that key end-users can immediately integrate other geohazards information into their GIS systems and develop priority visualization outputs.**

III. **The capture of all data from GeoNet GPS stations should be real-time streamed and fully integrated with the LINZ PositioNZ network with the effect that the location of hazard events such as earthquakes and tsunamis could be better characterised, and the network better utilised for non-hazards applications.**

IV. **Investigate the use of cloud-based archive solutions and the use of these techniques to expedite the establishment of a back-up capability for earthquake and other hazards processing and archiving offshore.**

V. **Give priority for the development of web-based data access (WMS and WFS) using open standards to allow easy discovery and availability of GeoNet data and information in geospatially enabled form for easy use by GIS and other visualisation systems.**

Data Dissemination

The previous section discussed the improvements in the collection, processing and dissemination of information to technical professional and scientific users, while previous parts have discussed the advantages of the open data policy making all monitoring data freely available in real time and at no cost.

A major change since the 2008 review has been increased public profile and the increase in the use of the GeoNet website by the public. There were a billion hits in 2011/12, with a peak rate of over 16,000 per second. The GeoNet website has become a highly visible, trusted and reliable resource and has been the source of information for real-time hazard information since the Canterbury earthquakes, for both technical users and the general public.

Improvements through automation of initial earthquake location and magnitude determination has provided users with state of art information. Within 5 minutes for large earthquake and under 2 minutes for smaller but significant events. In addition to the main webpage on GeoNet, data is also disseminated to the stakeholders using mobile phone applications. In addition, two-way communication with the public is now occurring through social media links such as Facebook and Twitter. The GeoNet website also now provides complete earthquake event access to strong motion data, in a format familiar to the professional engineering community (COSMOS), via its ftp site.

In the case of volcanoes there have been improvements with the move to include regularly updated JPEG camera images and current up to date warning information While there have been major improvements in data dissemination for earthquakes and to a lesser extent for volcanic hazards as well, there has been little progress on tsunami (where coverage is limited to static sea level and gauge information) and landslips (which is essentially limited to reports on particular locations).

Looking ahead the Panel's view is that while current efforts to inform the general public should be sustained, the priority for further effort should be for technical professional and scientific users. The GeoNet web delivered during the Canterbury earthquakes, it is now time to re-focus onto the "professional" users. **The main priority is improvements in access to data at the GeoNet website to the research and engineering communities by providing a better user interface to search through the large and increasing volume of data being generated by the system**. For example, a user should be able to request event data at a particular station, within a range of dates, and for events within a certain distance of the station. Similarly, a user should be able to search on stations utilizing parameters of the metadata for that station. The simplest example here is just the ability to search for metadata from stations within user requested coordinates.

Consideration should also be given to improving the look and feel of the GeoNet home page. We understand that having a simple home page is critical during a major earthquake sequence to handle the throughput needed when a very large portion of the public is coming to the site for information. However, the one suggestion is that a more elaborate flashy home page be used in "peacetime", with current news events and images, and links to the various instrumentation activities and hot new research being done with GeoNet data. Web-statistics could be monitored so that if the number of home page hit rate increased above a certain level, the default home page automatically switches to the simpler page. Other suggestions include that consideration should also be given to providing a link on the GeoNet website to refereed scientific publications that acknowledge significant use of GeoNet data as well as to the research web-pages at GNS Science that are based on significant use of GeoNet data.

Commendations

I. **GeoNet is wisely at the forefront internationally in its policy of open access to monitoring data, contributing to its credibility as the authoritative voice on New Zealand geo-hazards.**

II. **The management of the GeoNet Project deserves much credit for the significant improvements in the collection, processing and dissemination of information on earthquakes and volcanic hazards to both the general public and technical professional and scientific users.**

Recommendations

I. **Access to data at the GeoNet website should be improved upon to provide the research and engineering community with a better user interface that enables improved search.**

II. **That the focus development effort on data dissemination should be on the needs of scientific and selected business users rather than enhanced functionality for the general public.**

III. **Investigate improving the look and feel of the GeoNet home page with links to the various instrumentation activities and new research underway**

IV. **That the option of providing a link on the GeoNet website to refereed scientific publications than have made significant use of GeoNet data should be investigated.**

Part G - Governance and Management

Contracts and funding

GeoNet is run as a project within GNS Science, a 100% government-owned Crown Entity company incorporated under the Crown Research Act 1992. GeoNet employs 35 FTEs which is around 10% of total GNS Science staffing. 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 EQC is a statutory Crown Entity established under the Earthquake Commission Act 1993 and governed by the Crown Entities Act (2004) where it is listed in Schedule 1 Part 1 as a Crown agent. As the EQC is the owner, the fixed assets of GeoNet are held on the EQC's balance sheet and the intellectual property (IP) is vested in the EQC. GNS Science is licenced to use any IP created by GeoNet on a royalty-free basis (Clause 12.2).

There is a formal Purchase Agreement (PA) between GNS Science and the EQC. In principle, as both are separate legal entities, this legal contract is potentially enforceable by law. In practice the Government, which owns 100% of both parties, would take a dim view of one taking legal action against the other. The PA in turn refers to an Annual Work Plan and Business Plan.

There is a yawning gap between legal form (the black letter of the contract) and the reality of the relationship. The PA is worded as an arms-length contract for delivery of IT services. The contract makes no explicit provision for revision of the Annual Work Plan once the year has begun. Indeed other than Clause 4 ('time not of the essence') the PA reads as a standard arms-length IT services contract with little provision to provide for within-year adaptability or flexibility to handle emergent developments. While this might have been appropriate at the time GeoNet was established, when the imperative was the establishment and roll-out of a new capability, the project has since matured.

In reality the way the relationship now works is different to what is provided for in the contract. In practice the 'implicit contract' between the parties is not for the EQC to purchase defined capital projects and delivery of pre-specified IT services. Instead it is more of an alliance or partnership relationship where the understanding amongst the parties is that GNS Science has entered into a funding arrangement with the EQC for the GeoNet project. The EQC as 'owner' undertakes to deliver a defined funding stream over a sustained period (2010 – 2020), with a review in 2014 to determine the next five years' funding. In return for this commitment GNS Science as 'service provider' undertakes to put this capped funding stream from the EQC to best possible use. Based on the funding commitment, GNS Science can commit to hiring staff and building system capability. Over time the practice has grown up such that GNS Science has the flexibility within the year to vary the mix of capital spend from the agreed programme and to vary the mix between capital and operating. This flexibility has allowed GeoNet to rise to the challenge posed by major hazard events. These hazard events during the period since the last review in 2008 include the four major Canterbury earthquakes and associated aftershock sequence, three tsunami events, and volcanic eruptions at Tongariro and White Island. The details of the achievements are discussed in the introductory chapter that reviewed GeoNet's performance since the last review in 2008. In particular we support the decision to divert investment from other areas to reinforce the seismic network in the Canterbury area following the first earthquake in September 2010. While serendipitously it was possible to manage the response to the Christchurch earthquakes by altering the roll out of seismic equipment to new sites, this may not always be possible. For example, as noted earlier, the response to the short Tongariro eruption in August 2012 stretched the resources available. We note that a concern that emerged in the workshops was the need to provide surge capacity to respond to hazards such as a sustained volcanic eruption. The heavy cost burden of Christchurch's recovery should not be allowed to impact financial support for GeoNet. It is obvious that the occurrence of a disaster does not make another disaster, and hence the need for vigilance and planning, any less likely.

To date the flexibility to respond to unexpected or emergent events is allowed for in the way that the deliverables are specified in the Work Plan. The schedules for the Annual Work Plan are specified at a very aggregate level (capital on 'network upgrades', operating expenditure on 'management services') rather than specifying in detail the services to be supplied or the sites to be built or upgraded. In practice we understand the main thing that is varied within and between years is the roll out of new sites and the upgrade of sites. While there is no formal change procedure with the EQC, in practice GNS Science run a 'no surprises policy'. Changes are signalled by email to the EQC and reported formally in the quarterly reports. The panel's view is that the formal PA doesn't reflect the nature of the underlying implicit contract between the two, nor provide the flexibility that would be needed to respond to hazards such as a sustained volcanic eruption. Accordingly the contract should be revised to formally provide for the required within-year flexibility.[3]

This might seem like a 'tidy minds' solution generating a 'make work scheme for the lawyers'; however, the recommendation is based on concerns about the resilience and sustainability of the GeoNet project. In good times where there is good will, good relationships and strong performance the contract is essentially irrelevant. Where the contract matters is when things go wrong. The panel noted that on 18 September 2012 the Government announced that the Treasury will lead a legislative review of the Earthquake Commission Act 1993. This review is intended to draw on the lessons learned about the operation of the legislation in the responses to the Canterbury earthquakes and other events over the past 20 years. This review may result in the existing relationships being disturbed. A new interlocutor representing the funder may refer back to the formal contract to look to put the relationship back on a firm legal foundation. It is important that at the appropriate time, the contract is brought more into line with the modus operandi of the parties. The obvious time to do this is as part of the review of funding renewal in 2013 due to take effect in 2015.

The panel recommends that as part of the preparation for the 2015 funding review both parties review the contract in 2013 to ensure adequate flexibilities are included, for example by explicitly providing in the contract for within-year variations in the Annual Work Plan, by a process specified in the Annual Work Plan.

[3] The 2008 Review Panel discussed (p13) the use of an 'evergreen' contract including a longer termination clause (one to two years) available to either party. Transpower and Electricity Commission provide a New Zealand example of this sort of arrangement.

Business planning

In order to implement the contract and funding arrangements discussed in the previous section, GNS Science has developed a Strategic Plan, a multi-year Work Plan (the current version dated September 2009 covers 2010-2020) and an Annual Project Work Plan.

A strategic plan can be expected to cover the big questions:

1. What is the business – what products, services, markets?
2. Who are the customers and stakeholders – what market segments, competitive advantages, marketing strategy?
3. Where are we now – what does the situational assessment show?
4. Where do we want to go – what is the hierarchy of objectives?
5. How will we get there – what strategies, tactics and programmes?
6. What will be required– what staff, management, operations, marketing?

The planning documents reviewed contain good coverage of what is required to operate GeoNet as a business. In particular there was a very strong emphasis on operational objectives, financial modelling and the long term financial sustainability of the operation. For example the Annual Plan includes *Maintenance Equipment Replacement* and *Capability Strengthening* as one of five development objectives. There was less emphasis on marketing and customer perspectives and the unique 'value proposition' of GeoNet. What seemed missing was the focus on the competitive advantage of GeoNet. Questions of competitive advantage include: in what ways is GeoNet distinctive and unique? And what niche should it occupy?

Clarity in prioritising objectives and customers will assist management to distinguish a blind alley from a genuine window of opportunity. The Strategic Plan needs to set out the filters or tests that GNS Science staff should use to assess proposed variations to the GeoNet Annual and long-term Work Plan. These filters should be developed with the co-operation of all funders, in particular with buy-in from the EQC. These filters should be applied by GeoNet management to review and screen all planned projects (such as those proposed in this report) and to respond to emergent developments (such as deployments in response to an emergency).

By filters or tests we would suggest (a more refined version) of something along the following lines:

- How does this development utilise GeoNet's unique value added (if we didn't do this who else would)?
- How much strategic alignment is there (how much public value does this generate by contributing to the vision and mission)?
- How well does this match GeoNet's unique capabilities (is this an extension of a current core capability or the addition of a new role)?
- What priority does this have relative to available capacity (is there a paying customer for this deliverable or capability)?
- What are the long-term sustainability implications (what is the through-life cost of sustaining this)?

The panel recommends that the Strategic Plan be updated to provide filters or tests that GNS Science management should use to assess proposed variations to the GeoNet Annual and long-term Work Plan. These filters should be applied to review and screen all planned projects (such as those proposed in this report) and to respond to emergent developments (such as deployments in response to an emergency).

Engagement with stakeholders

GeoNet provides a textbook example of effective interagency collaboration.[4] The design of governance arrangements for interagency working needs to address both 'hard' and 'soft' factors. The so-called 'hard' or 'objective' factors relate to the systems, structures and institutions involved. Ironically these 'hard' factors are the easiest to address. The 'soft' or 'subjective' factors relate to people and relationships. The 'soft' factors are the hardest things to get right. Getting the soft factors to work together creates a sense of shared responsibility and positive group dynamics and behaviours (Boston and Gill 2011). The literature on corporate governance suggests that getting the hard factors right is neither necessary nor sufficient for achieving high quality governance. In other words, getting the structure right is only a minor part of the story.

In the workshops, discussion emphasised some of the hard factors that were critical to the success of this arrangement. These serendipitous hard factors include that the EQC had its own Act which required a board to focus on the need to 'take care of tomorrow today.' In addition the EQC has a dedicated source of levy income, which enables the board to confidently make long-term commitments. The GeoNet partnership has contributed to the EQC's mission of better management of natural hazard long-term risk.

To these hard factors the panel would add the role of soft factors relating to people and roles identified in other research (Ryan et al 2008). These soft or subjective factors include creating social capability, positive group dynamics and behaviours, leadership, followership and a sense of shared responsibility.

Throughout the development of the GeoNet project the EQC has acted neither as a purchaser nor a passive funder; instead they have acted as an active sponsor. For example, as part of the 2005 funding review, a condition of funding was a requirement that GNS Science formalise relationships with MCDEM, the CAA and Local Government amongst others. By brokering these Memorandums of Understanding, the EQC laid the ground for GeoNet to grow and develop deeper relationships with key partners in the emergency response sector.

Looking at GNS Science as an organisation, it has not treated GeoNet as an ancillary operation. GNS Science has been an active host of the GNS Science project, providing resources as required to do what needed to be done. In short, GNS Science has sustained and supported the growth of GeoNet. GNS Science brings a depth of scientific expertise and capability plus sound corporate management systems. In GeoNet they have created an adaptive, resilient, flexible structure able to adapt quickly and cheaply to changing

[4] See Ryan et al (2008) for New Zealand case studies of eight different ways of inter-agency working http://igps.victoria.ac.nz/events/completed-activities/joiningup.html

circumstances. The project structure combines all the advantages of a large organisation (resilience and depth of expertise) with all the advantages of a small organisation (adaptable, responsive and flexible).

It is important to note that after the establishment and development phase, the success of the GeoNet partnership between the EQC and GNS Science has attracted other partners as 'nothing breeds success like success.' GeoNet now has a range of other funding partners include LINZ (PositioNZ GPS network and tsunami monitoring), Ruapehu Alpine Lifts, KiwiRail, the airlines (through the MetService) and direct Crown funding for Geo-Chemistry.

Nonetheless the panel notes the on-going risk that outside of the EQC and GNS Science, the commitment to GeoNet while wide is not deep. The EQC remains 'the cornerstone investor.' It remains important to build the political capital of GeoNet and to look for opportunities to expand the range of potential funders. The rapid adoption of web-based and smartphone-based applications has raised the public profile of GeoNet significantly. These need to be maintained but any expansion in public-facing capability will need a robust business case. Another way to expand the political capital of GeoNet is to update the business case for GeoNet. In 2009 the EQC commissioned a Cost/Benefit Analysis of GeoNet from NZIER[5]. As discussed in Part A (above) it is important that this CBA is updated to keep abreast of developments and to assist with the continued engagement with various stakeholders on the unique value proposition of GeoNet.

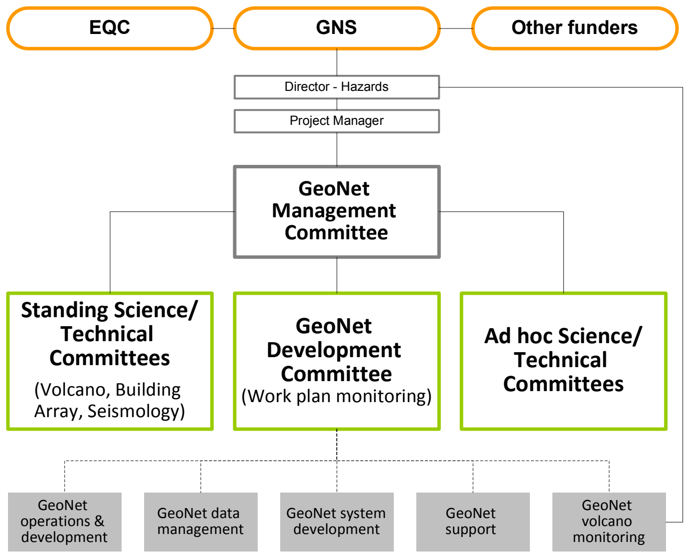
Management arrangements within GNS Science

As previously discussed GeoNet is run as a project within GNS Science. This has a number of advantages in that the project can access the wider resources of GNS Science when required. When not required these resources have another home and are not a charge to the project. This gives the project flexibility, sustainability and resilience. As the previous review examined the structure, staff and systems in more detail than was allowed in the workshop format used in this review, we have focused more on recent developments and emerging issues.

GNS Science has entered into a long-term agreement for the supply of services to the EQC and has shorter-term funding arrangements with other funding partners such as LINZ (GPS network and tsunami monitoring), Ruapehu Alpine Lifts, KiwiRail, the airlines (through the MetService) and direct Crown funding for Geo-Chemistry. In brief the structure of the GeoNet project is shown below as Figure 1.

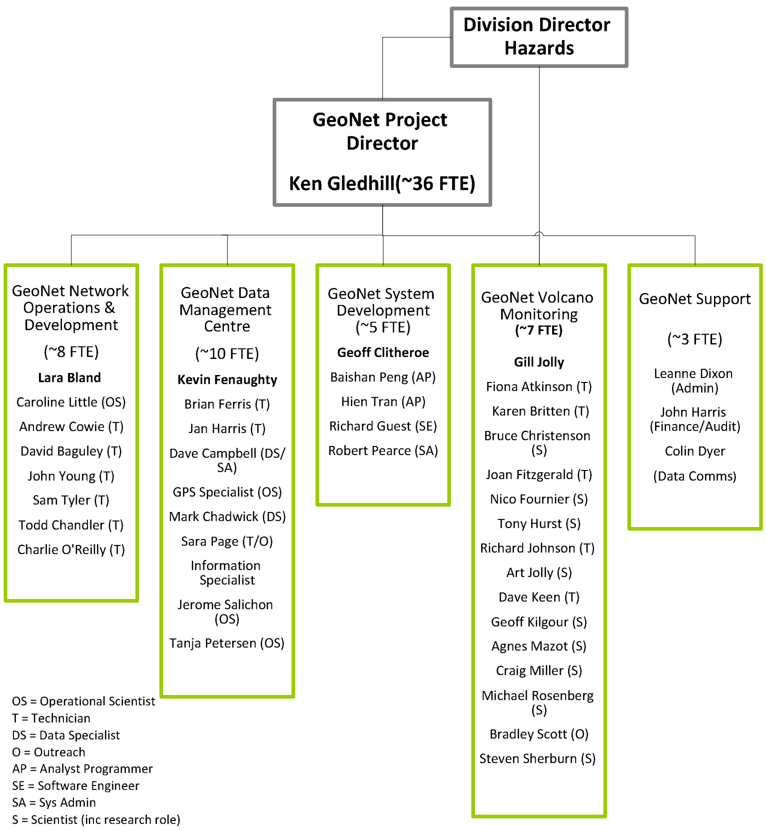
[5] One of the review panel is employed by NZIER. The panellist was not involved in the CBA.

Figure 1 – GeoNet Project Governance Structure



The GeoNet Management Committee has oversight over the whole project. It is assisted by the Development Committee which performs a Project Work Plan oversight and monitoring function. This is augmented by Ad Hoc Technical Committees on issues such as instrumentation and Standing Technical Committees for the various hazard domains.

Figure 2 – GeoNet Project Staffing



GNS Science in part uses a matrix management structure. For example the Volcano Department Head reports to the Divisional Director in the line management structure (shown by the firm line in Figure 1) as well as to the GeoNet project manager on day to day GeoNet issues (shown by the dotted line in figure 1). The staffing structure of the GeoNet project (but not the line management structure within GNS Science) is shown in Figure 2.

The introductory chapter that reviewed GeoNet's performance since the last review in 2008 highlighted the issue of succession planning. GNS Science and the EQC need to work on succession planning to ensure that the partnership continues in the event of the departure of either of the two senior relationship managers (the GeoNet project manager and the EQC General Manager Reinsurance Research and Education) involved in the oversight of project.

Finally regular reviews are conducted on the operation of GeoNet with the last review conducted in 2008. For this current review the process was a two day gathering that allowed GeoNet staff and a broad range of professional uses to provide a wide range of possible options and developments for the future. The previous Review was two days of detailed presentations with GeoNet staff and a small number of selected users. The Review team believe that a more efficient outcome would be achieved by rebalance these two generic approaches.

Commendations

I. **GNS Science and the Earthquake Commission (EQC) have worked together to develop a long-term, high-trust, mutually beneficial partnership. Together in GeoNet they have created a gem – a brilliant example of government agencies collaborating effectively together to create public value.**

II. **The EQC brings the ability to commit to be a long-term funder and sponsor in order to deliver its mission of better management of natural hazard long-term risk.**

III. **GNS Science brings a depth of scientific expertise and capability plus sound corporate management systems.**

IV. **Together in GeoNet they have created an adaptive, resilient, flexible structure which combines all the advantages of a large organisation (resilience and depth of expertise) with all the advantages of a small organisation (adaptable, responsive and flexible).**

V. **The success of the GeoNet partnership between the EQC and GNS Science has attracted other partners as 'nothing breeds success like success'. GeoNet now has a range of other funding partners such as LINZ (GPS network and tsunami monitoring), and Ruapehu Alpine Lifts. However the EQC remains 'the cornerstone investor'.**

VI. **The planning documents have good coverage of what is required to operate GeoNet as a business, with a particularly strong emphasis on operational**

objectives, financial modelling and the long-term financial sustainability of the operation.

VII. **The quality of the relationship between GNS Science and the EQC is crucial to the on-going success of GeoNet. The panel note that while there is clearly a highly professional, high-trust relationship between the EQC and GNS Science, this is largely due to the professional relationship between the two senior personnel; Drs Hugh Cowan and Ken Gledhill, which on the EQC side does not extend much wider. As a result there are a number of recommendations on issues such as building more adaptive capacity into the EQC- GNS Science contract, emphasising succession planning and diversifying GeoNet funding sources, and continuing regular external reviews which will all be very important for the on-going success of GeoNet. In the future the review process should allow the Review Team more time for direct access and discussions with GeoNet staff, for example one day with a wide range of stakeholders, and one day with GeoNet staff.**

Recommendations

I. **The panel recommends that as part of the preparation for the 2015 funding review, the parties review the contract in 2013/14 to ensure adequate flexibilities are included. For example the contract should explicitly provide for 'within-year' variations in the Annual Work Plan, by a process specified in the Annual Work Plan.**

II. **The panel recommends that the Strategic Plan be updated to provide filters or tests that GNS Science management should use to assess proposed variations of GeoNet activity. These filters should be applied to review and screen all planned programmes (such as those proposed in this report) and in responding to emergent developments (such as deployments in response to an emergency).**

III. **GNS Science and the EQC need to work on succession planning to ensure that the partnership continues in the event of the departure of either of the two key senior people involved in the governance of project.**

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Annex A - Panel Profile

Jarg Pettinga

Professor Jarg Pettinga heads the Department of Geological Sciences at the University of Canterbury. His research interests include the study of active tectonics and structure along the New Zealand plate boundary zone, the role of tectonic and climatic forcing in triggering large bedrock controlled landslides in landscape evolution, paleoseismicity and earthquake hazard assessment with particular emphasis on the Canterbury region. Jarg has been an expert witness for the Royal Commission hearings on the Canterbury earthquakes. He is a current member of the Management Group for the Natural Hazards Research Platform charged with overseeing and coordinating national research funding investment by Government. He gained his BSc and PhD from the University of Auckland and is a Fellow of the Geological Society of America.

Kieran Devine

Kieran Devine is an electrical engineer with more than 30 years' experience within the electricity industry both in New Zealand and abroad. He is currently General Manager, System Operations for Transpower New Zealand Ltd, the owner/operator of New Zealand's high-voltage electricity transmission grid. As System Operator, Kieran is responsible for real time Scheduling, Despatch, and Security of the New Zealand Power System, together with the management of the real time aspects of the Wholesale Electricity Market. He completed bachelors and masters degrees in engineering at the University of Canterbury, and an MBA with Distinction from Victoria University of Wellington. Kieran is a Fellow of the Institute of Professional Engineers (NZ), a Senior Member the IEEE (USA), and a Member of the IET (UK). He is also a member of the Institute of Directors of New Zealand, a Trustee of the Centre for Advanced Engineering, (CAE), and a past Chairman of the New Zealand Electricity Market, Rules Committee.

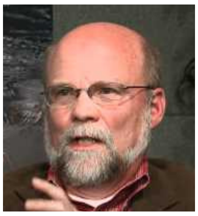
Derek Gill

Derek Gill is Principal Economist for NZIER. He has a passion for public management and public policy and has been applying economic and financial analysis to a range of practical policy problems for his entire working career. In recent years he has extensively researched, taught and published on a range of public policy and management issues, while based at the Institute of Policy Studies at Victoria University. His previous experience spans work in the public and private not-for-profit sectors and included roles; as a general manager in a service delivery organisation, with the OECD and central agencies in New Zealand, as well as a diplomat and policy advisor. He has served as a long standing Board Chair and Treasurer on a number of voluntary organisations. His academic qualifications are BA (Hons), Dip. Acc. and MA.

Jamison H Steidl

Dr Jamison H Steidl is a Research Seismologist and Adjunct Professor at the University of California, Santa Barbara's Earth Research Institute. After completing his BS and MS degrees at Rensselaer Polytechnic Institute (RPI) he obtained a PhD in Earth Science from the University of California, Santa Barbara, studying near field ground motions.

Currently, Dr Steidl is the Principal Investigator of the NSF George E Brown Jr, Network for Earthquake Engineering Simulation (NEES) Permanently Instrumented Field Sites Facility, which is designed to provide the observational case histories from earthquakes that will allow for improvements in the prediction of ground shaking from earthquakes including non-linear soil behavior, soil-foundation-structure interaction, and liquefaction. He is also responsible for the Southern California Earthquake Center's (SCEC) Portable Instrumentation Center and Borehole Instrumentation Program, serves as an advisor to the US Geological Survey's National Strong Motion Program, and is currently serving as the Secretary of the Consortium of Strong Motion Observations Systems (COSMOS) Board of Directors. Dr. Steidl is a member of the Earthquake Engineering Research Institute (EERI), the Seismological Society of America (SSA), and the American Geophysical Union.



John Eichelberger

Dr John Eichelberger is currently taking over the position of Dean of the Graduate School, University of Alaska (Fairbanks), having just relinquished a position he had from 2007 as Volcano Hazards Programme Co-ordinator for the United States Geological Survey. He has around 40 years of experience as a volcano expert, is a former chair of the University of Alaska (Fairbanks) Department of Geology and Geophysics, professor of volcanology and coordinating scientist with the Alaska Volcano Observatory (AVO). He graduated in 1974 with a doctorate in geology from Stanford University and in 1971 from the Massachusetts Institute of Technology with bachelor's and master's degrees in earth sciences.

Tomoaki Ozaki

Tomoaki Ozaki is the Senior Coordinator for Tsunami Forecast Modelling, Earthquake and Tsunami Observations Division of the Japan Meteorological Agency (JMA).

Since he entered JMA in 1989, he has experienced various tasks on meteorology, seismology and administrative matters such as numerical weather prediction, international affairs, seismological data processing, administration of disaster management, and earthquake/tsunami monitoring. Currently he is in charge of coordination on tsunami forecast modelling.

Kristine Asch

Dr Kristine Asch, a geologist, heads the Geological Information Systems and Maps unit at the Federal Institute for Geosciences and Natural Resources (BGR). She is Secretary General of the IUGS Commission of Geoscience Information (CGI) and coordinates the CGI & UNESCO Geoscience Information in AFrica (GIRAF) network.

As a member of both the European Union Drafting Team "Data Specifications" and the national INSPIRE Task Force, Kristine is involved in creating the implementation rules of the new EU directive INSPIRE and is responsible coordinator of the contributions to be made to INSPIRE by the geological surveys of Germany.

Dr Asch coordinated the BGR contribution to the German R & D project SLEWS (Sensor based Landslide Early Warning System) and is a member of the team of the global OneGeology project which aims to globally make geological map data accessible for everyone via the internet.

Since 1995 Dr Asch has led the IGME5000 project: a multi-national initiative to create a harmonised geological map and geographic information system for Europe, which she made available as a web mapping application.