Catastrophe Risk Appetite

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Introduction

The Pacific Ring of Fire runs straight through the heart of New Zealand. This is where the Australian and Pacific continental tectonic plates collide resulting in earthquake and volcano activity throughout the country. New Zealand's two biggest cities are both built in high risk zones, with Rangitoto being a constant physical reminder of the volcanic risk to Auckland and Wellington regularly experiencing earthquakes. The most material earthquake to impact Wellington in recent times was the 14 November 2016 Kaikoura earthquake. In 2010/11 New Zealand's third biggest city of Christchurch experienced a number of earthquakes and aftershocks, including the 22 February 2011 earthquake which was the most catastrophic of the sequence and resulted in the loss of 185 lives. The insurance industry including the EQC and the Government is continuing to manage the aftermath of this event seven years later.

Property insurers generally underwrite risks throughout NZ and therefore they need to have a full understanding of the underwriting and catastrophe risk they are accepting. Regardless of the amount of reinsurance protection purchased, capital held and decisions made, there will always be some risk, however small, that a catastrophic event will lead to economic ruin. It is appropriate to consider the risks from these extreme scenarios and consider the "what if…?" questions regardless of the small probabilities of these occurring, in order to increase insurers' resilience to these events.

For most general insurers in New Zealand, catastrophe risk can potentially lead to intervention by the RBNZ and in the worst case scenarios lead to economic ruin. It is extremely difficult to assess this risk given the low frequency and high impact of the events we are considering. It is therefore appropriate to consider catastrophe risk in a systematic way for Management and the Board to understand the risk to their company's long term sustainability.

Purpose of paper

The purpose of this paper is to present a framework to analyse catastrophe risk in a systematic way. The proposed framework is for Management and the Board to follow to assist them to understand and articulate their risk appetite to this catastrophe risk. The framework uses Realistic Disaster Scenarios ("RDS") to achieve this. The risk appetite needs to balance the long-term sustainability of a company with that of remaining competitive in the market, thereby maintaining shareholder value through measured decisions on the level of risk accepted. The risk appetite should consider capital, underwriting, modelling risk and reinsurance (both retention and upper limit).

The risk appetite needs to consider Management and the Board's tolerance to events i.e. Is there a probability that would lead to a change in risk appetite to safeguard their company? E.g. a 1% probability of the Wellington fault rupturing may be acceptable, but what if it was a 20% probability? At what probability does the Board and Management decide that the risk is unacceptable and withdraw or restrict capacity in high risk zones?

The presented catastrophe risk appetite framework ("Framework") is designed to fit into the overall risk appetite of a company. Whilst the Framework is designed to consider the catastrophe risk from earthquakes and volcanoes, it can also be used to assess other risks such as flooding, tsunamis and the impact of climate change.

Use of GeoNet Data

I acknowledge the New Zealand GeoNet project and its sponsors EQC, GNS Science and LINZ, for providing data used in this paper.

Any reference to magnitude[1] refers to a measure of the energy released by an earthquake at its source. Magnitude is commonly determined from the shaking recorded on a seismograph. Each unit of magnitude on the scale represents a substantial increase in energy, for example a magnitude 5 releases 30 times more energy than a magnitude 4.

General Risk Appetite framework

The Framework builds on the work carried out by the Actuaries Institute's Risk Appetite for General Insurance Working Party's 2016 paper titled "Developing the Risk Appetite Framework of a General Insurance Business"[2]. By going through this Framework, Management and the Board can set out the following in a structured manner:

1. Risk Appetite Statement – The aggregate level and type of risk an institution is willing to assume or avoid, within its Risk Capacity to achieve its strategic objectives and business plan;
2. Risk Capacity – The maximum level of and type of risk an institution is able to support before breaching constraints determined by regulatory capital and liquidity needs and its obligations to customers, shareholders and other stakeholders; and
3. Risk Tolerances – The quantitative measures and qualitative assertions for the maximum risk allowed by the appetite.

Catastrophe Risk Appetite Framework

Appendix A sets out how the Framework can be used to understand, assess and articulate a company's risk appetite to catastrophe risk.

The challenge with any risk appetite is to decide what your appetite truly is and what it means in practice i.e. why am I willing to accept a 0.025% chance of the company facing ultimate ruin but not 0.05%.

The Framework considers the impact on customers, communities, government, regulators, partners (brokers or banks) and shareholders. Given the nature of the risk it relies heavily on qualitative measures but is underpinned with a quantitative analysis of the impact on a company's enterprise value from these extreme events.

Enterprise Value to assess risk

Enterprise value ("EV") is an economic measure reflecting the market value of a company and a proxy for shareholder value. All Management's actions potentially have an impact on profitability and therefore either have a positive, negative or neutral impact on a company's EV.

For the purpose of the Framework an assumption was made that EV = 20 * post tax annual profit.

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[1] https://www.geonet.org.nz/earthquake/glossary
[2] https://www.actuaries.asn.au/Library/Events/GIS/2016/PaperCohenWhite.pdf

The hypothetical example below shows how the EV concept can be used to assess a decision being made by an insurance company ("Company ABC Ltd") to stop underwriting property insurance in New Zealand and become a motor insurer only.

ABC Ltd is a nationwide insurance company that underwrites in some high risk locations. Its annual profit is $50m per annum (comprising $25m property and $25m motor) which equates to an EV of $1,000m and it has a relationship with a national bank which delivers $10m of profitability from its motor portfolio.

ABC Ltd has put in place a reinsurance programme that satisfies the RBNZ 1 in 1000 year requirements with an upper limit of $1,000m.

The latest GeoNet data suggests that the annual probability of an event similar to that experienced in 1855 is 1% in the next annum. The estimated cost of this event derived from modelling is $2,000m.

Management are considering the financial implications of stopping underwriting in New Zealand.

Option 1: Keeping the status quo but the $2,000m event occurs with annual probability of 1%

- Annual profit - $50m
- Net cost of the event - $1,000m + deductible
- Risk margin in addition - $400m (this may or may not unwind depending on experience)
- Reinstatement Premium paid $100m
- Run off capital charges – 10% * $1,000m = $100m
- Reinsurance capital charges – 2% * $1,000m = $20m

ΔEV (Allowing for GeoNet probability) = $(1,500m) * 1.00% * 20= $(300m)

Option 2: Only underwriting motor

- Loss of property profit - $(25)m
- Loss of bank partners profit - $(10)m
- EV multiplier - 20

ΔEV = $(35m) * 20 = $(700m)

From an EV perspective, a decision to continue to underwrite property in New Zealand is the rationale response ($300m versus $700m) but what if there was actually a repeat of the 1855 earthquake? This is what Management and the Board need to consider. Would the Board's decision be different if the GeoNet probability increased from 1% to 50%?

As can be observed the impact from option 2 is greater, so Management need to consider the significant impact of the $2,000m event which has a low probability with ceasing to underwrite property which has a $700m impact with near certainty.

In this example, a single scenario was considered but another lens to analyse the risk from extreme events is to use the Average Annual Loss ("AAL") i.e. Expected Value at Risk for those events in excess of a company's reinsurance limit.

What is a Return Period?

The other critical metric in assessing the risk from catastrophe events is the probability of occurrence and how these can differ from a return period. A return period is a metric used to give an idea of the risk associated with an event. It can differ from the probability of that event occurring in the near term and can be considered as a long term probability.

A return period for an event of 1 in 1,000 means that over a 10,000 year time horizon we would expect to see that event 10 times. In reality a 1 in 1,000 year event could occur tomorrow, next week, next year or hundreds of years from now.

There are earthquake fault lines that are time dependents whereby the longer the time since the last occurrence, this increases the probability of it occurring in the near future. Notable examples of New Zealand time dependent faults are the Alpine, Ohariu, Wairarapa and Wellington faults. Elsewhere in the world the Cascadia fault is a notable time dependant fault in the Pacific Northwest of America, it is estimated to have a 243 year return cycle but hasn't ruptured for 317 years.

The table below sets out New Zealand's time dependent fault lines and their long term average return period, the last time the fault ruptured and the annual time dependent probability assumed by the Risk Management Solutions Catastrophe model ("RMS").

The new RMS model has an option to model these faults either on a time dependent or time independent basis. This option can significantly impact the Probable Maximum Loss ("PML") and AAL.

Table 1 Time Dependent Earthquake Fault Lines

Fault	Alpine	Ohariu	Wairarapa	Wellington
Return Period	340 years	2,000 years	1,200 years	2,140 years
Last Event	300 years ago	1,100 to 1,200 years ago	161 years ago	300 - 500 years ago
Time Dependant Annual Probability	0.62%	0.04%	0.01%	0.04%

The following table provides the Geonet[3] probabilities of an event to occur in Central New Zealand in the next year and 10 years.

Table 2 Latest GeoNet Central New Zealand Earthquake Probabilities

	Magnitude Range	Chance of occurrence: Range (figures in brackets are best estimate)
Within year	M 7.8 or greater	0.3% to 3% (1%)
	M 7.0 or greater	2% to 14% (6%)
Within 10 years	M7.8 or greater	2% to 20% (7%)
	M 7.0 or greater	10% to 60% (30%)

The RBNZ solvency standard requires companies to have the capability through reinsurance or capital to withstand a 1 in 1000 return period insurance loss. This is different to a 1 in 1,000 year earthquake event. Depending on the location of the event on the fault line a 1 in 1,000 year earthquake event

[3] https://www.geonet.org.nz/earthquake/forecast/central_nz

can lead to a different insurance loss e.g. 1 in 10 year insurance loss or a 1 in 10,000 year insurance loss.

Location

The location of an event is equally as important as the probability of that event occurring. For example an earthquake directly under the Terrace in Wellington will have a different impact to one north of the city. Similarly the impact from a rupture on the Alpine fault will differ depending on whether the rupture travels north to south or south to north and the direction of the energy.

Another way to consider this risk is to consider Auckland. Auckland is built on a volcanic field and a volcano can occur anywhere on that field. A volcano erupting in the middle of Queen Street will have a significantly bigger impact compared to one in the Hauraki Gulf.

Volcanic Modelling in Auckland

Understanding the riskiness from volcanoes is more difficult because of the lack of observable information.

Eruptions on the Auckland volcanic field are assumed to occur on average every 2,500 year[4] which translates to an annual probability of 0.04%. However we can further refine this probability to assess the likelihood of a failure in a company's reinsurance programme by considering location.

This analysis involved assessing the impact of a hypothetical volcano over each square kilometre over a grid encompassing the Auckland land mass. This analysis was carried out twice, once assuming a volcano with a 2.5km radius (same size as Rangitoto) and one with a 5km radius. Within the area of the circle a damage ratio of 100% was assumed. The damage from ash clouds, tsunamis and other risks were ignored, although in the future we plan to model this.

Appendix D shows the output from this modelling.

The probability given a volcano occurred was estimated by:

$$\frac{\text{counting the number of modelled points exceeding the reinsurance programme}}{\text{total number of modelled points}}$$

Based on this rudimentary modelling the probability of ABC Ltd exceeding their reinsurance limit was estimated at 1% for the 2.5km radius and 10% for the 5% radius, given a volcano erupts.

[4] https://www.auckland.ac.nz/en/about/perspectives/leading-research-and-innovation/monitoring-aucklands-volcanic-field.html

What are the risks?

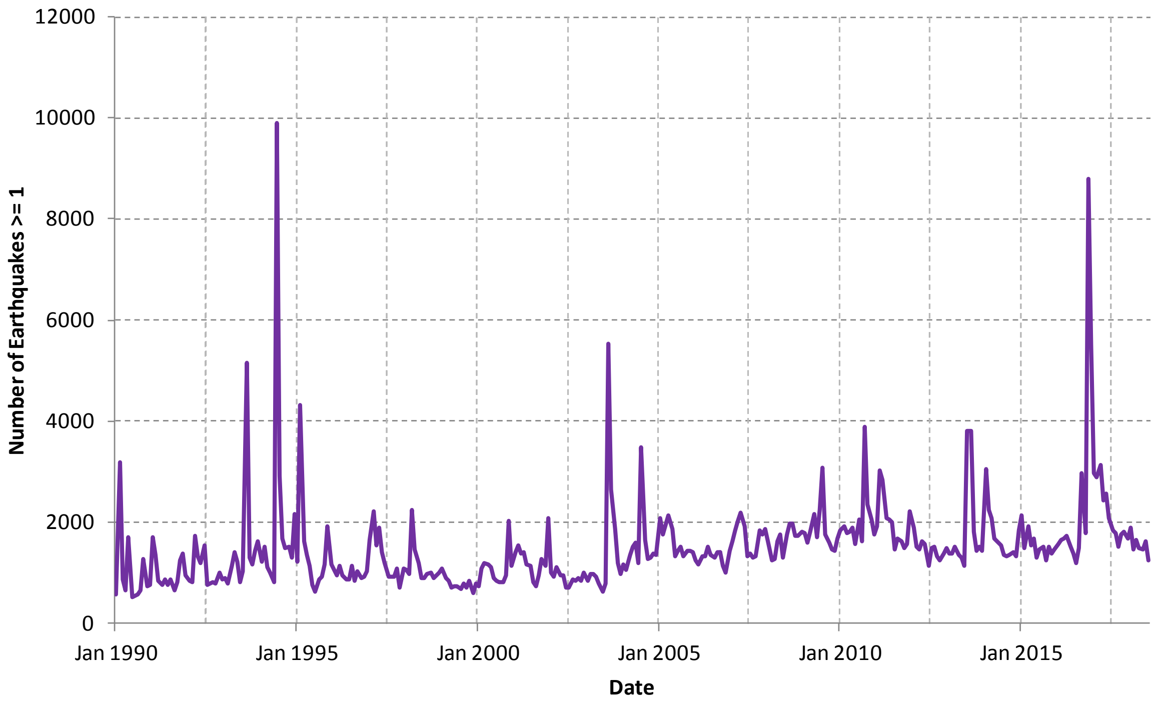
The main catastrophe risks to New Zealand come from earthquakes and volcanoes. Additional risks that are not covered include tsunamis that may develop from local events or events across the Pacific, or risks from climate change especially coastal inundation and flooding.

Every year New Zealand generally experiences circa 3,500 earthquakes of magnitude 3 or greater and circa 500 of magnitude 4 or greater. GNS actively monitor 12 volcanic areas in New Zealand. The table below shows the earthquake experience since 1990.

Table 3 History of Earthquakes by Magnitude based on GeoNet Data

Year	3 to 4	4 to 5	5 to 6	6 to 7	7+	Total
1990-1994	17,064	2,163	145	12	0	19,384
1995-1999	16,382	2,774	217	7	1	19,381
2000-2004	14,789	1,828	103	4	2	16,726
2005-2009	15,889	1,537	99	6	1	17,532
2010-2014	13,686	1,481	120	9	1	15,297
2015-2018	7,495	1,236	118	7	2	8,858
Total	85,305	11,019	802	45	7	97,178
Average	3,083	398	29	2	0	3,512

Figure 1 Time Series of the number of Earthquakes since 1990



Appendix B illustrates the risk to New Zealand from earthquakes and volcanoes:

- A list of the largest significant earthquakes to occur in New Zealand since 1848
- A map showing the location of volcanoes in New Zealand including the Auckland Volcanic field
- A summary of the number of earthquakes by five year bands.

The Catastrophe Risk Appetite Framework

Appendix A sets out the proposed Framework for Management and the Board to follow to understand and to articulate how much risk both are willing to take. The Framework provides the actuary with a considered way to present the risk return trade off which goes to the heart of any risk appetite discussion.

Consideration 1 - Do you want ABC Ltd to be a Property Insurer in New Zealand?

This is the most fundamental question of the Framework and isn't as obvious as you may think.

If the answer is yes, then Management and the Board need to accept that there is always the risk that regardless of the decisions made, capital held and reinsurance purchased, that ABC Ltd will risk regulatory intervention or even ultimate ruin in extreme cases.

If the answer is no, this could significantly impact the value of the insurance company due to the loss of customers.

In answering this question, Management and the Board need to consider the following:

- The size and type of events that could impact a company including the associated probabilities;
- The company's aggregate concentration;
- The impact on customers;
- The impact on the wider community;
- The impact on a company's partners (brokers, banks) and how this impacts the financial position;
- Reputational risk;
- Government intervention;
- The level of capital and reinsurance available before and after a significant event;
- The financial, capital and operational impact of potential events together with their associated probabilities;
- The impact on the enterprise value and therefore shareholder value; and
- The balance between long term sustainability versus market competitiveness.

Impact of an earthquake or volcano

In the event of an earthquake or volcanic event that impacts companies there will be known financial costs, but also secondary costs which may not be well understood.

There are four possible scenarios from a significant catastrophic event that, in extreme cases, could also impact companies:

1. The event is significant but well below a company's reinsurance upper limit and so the financial impact restricted to the net retention, a reinstatement premium and any additional claim handling costs incurred;
2. The event exceeds the reinsurance limit and leads to a significant impact on capital with a company breaching its licence condition leading to regulatory distress but assets are still in excess of liabilities. This leads to regulatory intervention and capital management;

3. The event exceeds the reinsurance limit and leads to liabilities exceeding assets but a company is still able to meet its obligations as they fall due. This leads to regulatory intervention, capital management and retrospective scrutiny of key decisions, arguably the Canterbury situation; and
4. The event exceeds the reinsurance limit and leads to liabilities exceeding assets and a company is not able to meet its obligations as they fall due i.e. Companies Act insolvency. This leads to regulatory intervention, capital management and retrospective scrutiny of key decisions.

Financial and Capital Impact

Following an event a company is impacted by the following:

- Immediate hit to the P&L of the reinsurance retention;
- Immediate hit to the P&L if the expected ultimate cost exceeds the catastrophe reinsurance programme;
- A payment of a reinstatement premium to restore its catastrophe programme, this cost is unknown and will depend on reinsurers capacity and appetite, in reality this sits on the balance sheet as a deferred reinsurance expense and amortised over the remainder of the financial year. NB that the reinstatement premium may have been prepaid but the company will want to purchase a third tower immediately;
- Due to the uncertainty of events (which can take several years to get better understanding of the risk) it is likely that a risk margin of several hundred millions would need to be added to any reserves potentially impacting both the P&L and capital of a company;
- A company will incur significant indirect handling costs not recoverable under its reinsurance programme;
- A Capital run off charge of 9% for Home Owner and 11% for Commercial Property;
- A reinsurance capital charge of between 2% to 40% depending on a company's programme; and
- A potentially significant impact on the solvency liability adequacy test from the deferred reinsurance expense with a corresponding impact to capital.

Operational and Opportunity Cost

Managing catastrophes increases the operational burden on claims and supporting teams such as loss adjusting, procurement, finance, actuarial and legal. This leads to increased operational risk and can potentially impact the performance of the business. Under the current Memorandum of Understanding between New Zealand insurers and the EQC whereby insurers handle all claims, this burden on the operational platform will be exacerbated, but ultimately will lead to a better customer outcome.

Managing significant events can also distract senior management from other strategic initiatives.

The reputational risk is also greatly increased from having to manage any claim management response.

Regulator

In the event that a company goes through its reinsurance programme and ultimately breaches its licence condition the Insurance (Prudential Supervision) Act (2010) gives the RBNZ wide ranging powers including statutory intervention, applying for liquidation and reducing the value of contracts.

In the event of a volcano that may shows signs of eruption a period of time before any damage, the impact will need to be factored in to the Liability Adequacy Test (which feeds into solvency calculation) and may result in a breach of a company's licence condition before any damage has been observed.

Customer and partner implications from restricting capacity

Restricting or the complete withdrawal of capacity in high risk zones would impact those customers within these zones. It is highly unlikely that they would be able to get insurance coverage at an affordable price. This would have knock on effects on the value of their assets and ultimately the ability for people to live in these zones without government support.

Broking partners would be impacted and more materially banking partners. The inability of bank customers to obtain insurance will have a detrimental impact on the value of the assets held as security for the written mortgages.

Some companies underwrite customers with properties throughout New Zealand including in perceived high risk areas. Any restriction of cover could lead to these companies insuring their assets with other local or international underwriters.

Balance between long term sustainability of a company with its competitiveness in the market

This question is at the heart of the risk appetite framework. It would be quite easy to look at the risks of the previous section and for the Board to take a conservative view and withdraw coverage. However, the Board needs to consider that reducing the risk of the portfolio has the potential for shareholder value to be lost.

Taking a conservative approach can quite easily destroy the value of a company if the actions adopted make it uncompetitive in the market place, whether that is purchasing excess reinsurance compared to other participants or by removing or restricting capacity in the market.

Getting that balance right is difficult. A competitor may decide to take the risk of inadequate reinsurance and adopt an overly optimistic model to model its reinsurance requirement thereby increasing its competiveness. That competitor will never be found out if their reinsurance programme isn't tested.

Consideration 2 - How much capacity are you willing to underwrite?

When the Board and Management answer this, they need to consider the company's strategy, the availability, structure and cost of reinsurance and capital.

It is at this stage of the risk appetite framework the Board should consider their appetite to modelling risk and whether it wants to hold any buffer to address the modelling risk.

Modelling risk
Appendix E sets out an excerpt from Guy Carpenter's 2011 report titled 'Managing Catastrophe Model Uncertainty – Issues and Challenges'. The paper highlights that at a 1 in 100 year return period, the range of uncertainty for US Hurricanes (better understood than earthquakes) goes from 50% to 230% of the modelled Probable Maximum Loss (PML).

The hindsight analysis of the catastrophe models following the Canterbury earthquakes demonstrated that the models didn't adequately model liquefaction. All models have flaws but they give Management a better picture of potential risks compared to not using them.

In deciding its risk appetite, the Board needs to consider whether a modelling buffer is required to allow for the uncertainty in the models.

Consideration 3 - What happens if the current portfolio and levels of capital and reinsurance is stressed against historical events?

The reinsurance programme of a company may be designed to satisfy the minimum RBNZ requirements but what happens if observed historical events are overlaid on the current portfolio.

Stress testing of portfolio aggregate portfolio

The stress testing of the portfolio uses Realistic Disaster Scenarios based on historical event. The table below gives an example of the stress testing of the ABC Ltd portfolio, it used the output from RMS modelling, but more rudimentary modelling can be used if a catastrophe model is not used. All the figures below have been manufactured for the purpose of this paper but give an understanding of the information that Management and the Board can consider.

Appendix C and D shows the output from the stress testing of the portfolio to earthquake and volcanoes.

Appendix E gives an overview of those historical events used in the stress tests.

Table 4 Stress Testing Example of ABC Ltd - Earthquake

Earthquake Event	Magnitude	Aggregate affected $m	RBNZ 1:1000 Gross Loss $m	Extreme >1:1000 event **Gross** Loss $m	Extreme >1:1000 event **Net** Loss $m	Period to Profitability Yrs
Alpine fault rupture	8.3	10,300	50	120	10	0.2
Christchurch earthquake	7.2	12,600	840	2,000	1,010	20.2
Hawkes Bay earthquake	7.8	10,600	580	960	10	0.2
Wairarapa earthquake	8.4	6,150	220	690	10	0.2
Wellington earthquake	7.4	7,125	533	1,545	555	11.1
Hikurangi subduction earthquake	8.6	22,800	570	1,710	720	14.4

Table 5 Stress Testing Example of Company A - Volcano

Volcano Radii	Probability of exceeding reinsurance programme	Largest **Gross** Loss $m	Largest **Net** Loss $m	Period to Profitability Yrs
2.5km	1.00%	1,143	153	3.1
5.0km	10.00%	2,763	1,773	79.2

Consideration 4 - What is your probability tolerance level and are there any scenarios that the Board is not comfortable with?

It is at this stage that these extreme scenarios and the probabilities associated with them are considered. Questions that should be asked:

- If the 1855 earthquake occurred tomorrow at an estimated cost of $2,000m, are we comfortable with this size of loss given a probability of 10%?
- What happens if the probability increases to 50%?

Once these tolerances have been set, these probabilities can be monitored through publically available information e.g. Geonet forecasts or by considering the frequency, size, depth and location of recent earthquakes.

Consideration 5 - Are you willing for ABC Ltd to underwrite all regions in New Zealand?

This follows on from the first question but you use the results of the stress test and other considerations to decide on restricting capacity and/or perils in different regions.

Consideration 6 - Are there any other management actions that should be adopted to manage ABC Ltd's exposure to catastrophe risk?

Once the overall risk appetite has been decided, are there any other boundaries that need to be incorporated to Management actions to ensure alignment with the risk appetite? These can include:

- Tailored restriction of coverage in selected areas;
- Increasing its reinsurance capacity; or
- Increasing the amount of capital held.

Once the Board have gone through this Framework and articulated its risk appetite, Management can then carry out its tactical approach e.g. optimising the portfolio for a given objective.

Example of a Risk Appetite Statement

Set out below is an example of a possible Risk Appetite Statement for ABC Ltd after going through the Framework:

Catastrophe Risk Appetite

Management is willing to underwrite all property risks in all areas of New Zealand for all natural disaster perils subject to standard underwriting controls.

Catastrophe Risk Capacity

The 1 in 1000 year requirement of the RBNZ Non-life Solvency Standard Probable Maximum Loss ("PML") of the aggregate used must not exceed the reinsurance limit of $1,000m.

Catastrophe Risk Tolerances

Management will monitor the annual probabilities published by GNS and Geonet for the risk of a significant event (an earthquake of magnitude 6 or greater and volcanic activity) in the Wellington, Christchurch and Auckland regions. Management will then put in place the following tolerances:

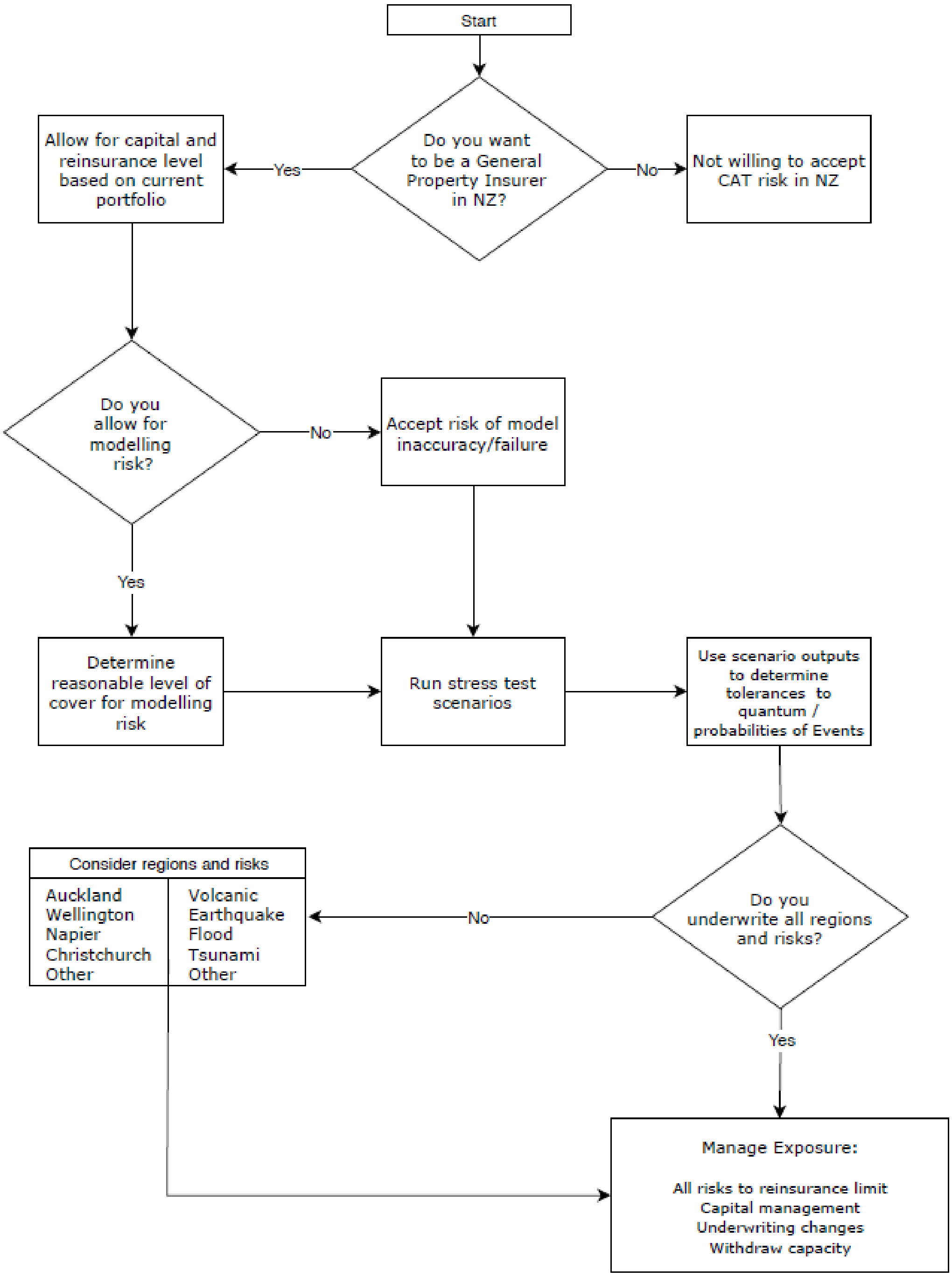
- *Annual probability of a significant event in the Wellington, Christchurch or Auckland region > 90% - review appetite to underwrite in the respective region*
- *Annual probability of a significant event in the Wellington, Christchurch or Auckland region > 95% - restrict or withdraw capacity in the respective region*

Conclusion

The Framework provides Management and the Board with a structured way of assessing the risk from extreme events that occur infrequently and to therefore articulate their risk appetite. The process of going through the Framework should be documented and in the unlikely event of a significant event that leads to economic ruin, this process acts as an insurance policy for Management, the Board and the Appointed Actuary to demonstrate that the risk was in fact adequately considered and assessed.

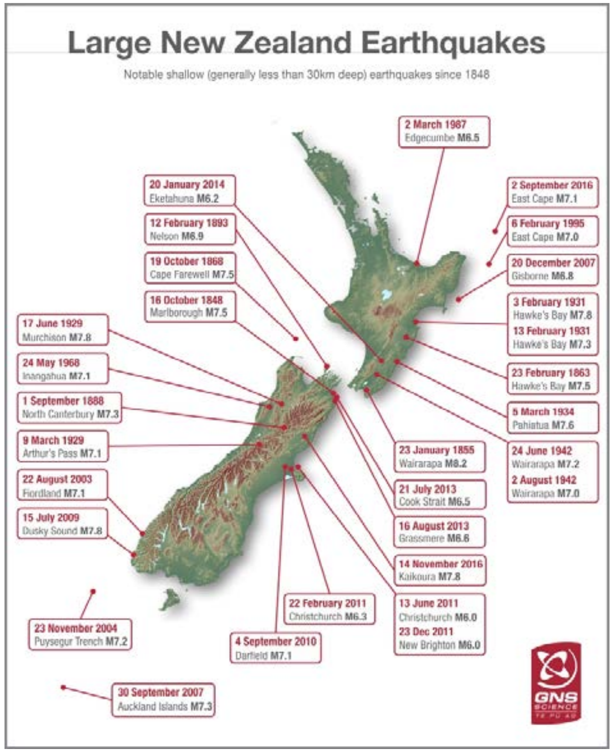
The key to this Framework is for Management and the Board consider the RDS. In this example ABC Ltd used the output from the RMS model, however any model including more rudimentary modelling using excel can provide valuable insights to assist in truly understanding the potential risk to companies.

Appendix A - Catastrophe Risk Appetite Framework

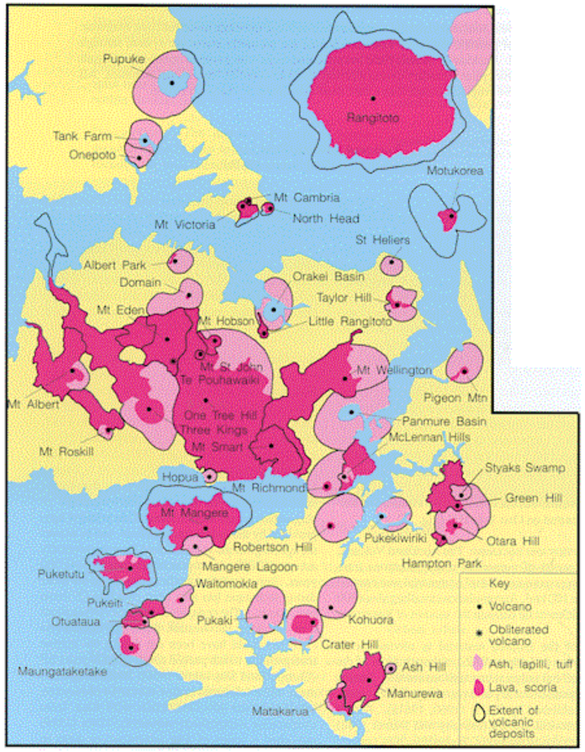


Appendix B – New Zealand Earthquake and Volcanic Risk

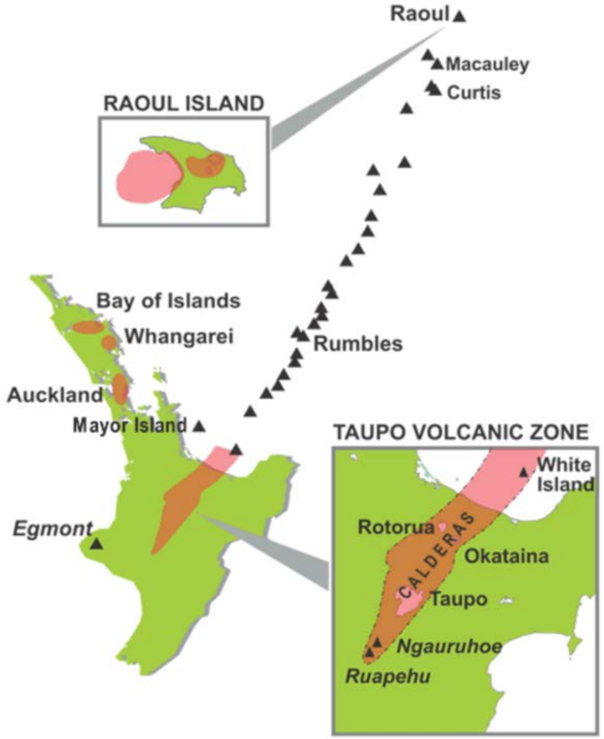
Notable NZ Earthquakes[5]



Auckland Volcanic Field[6]



New Zealand Volcanic Region[7]



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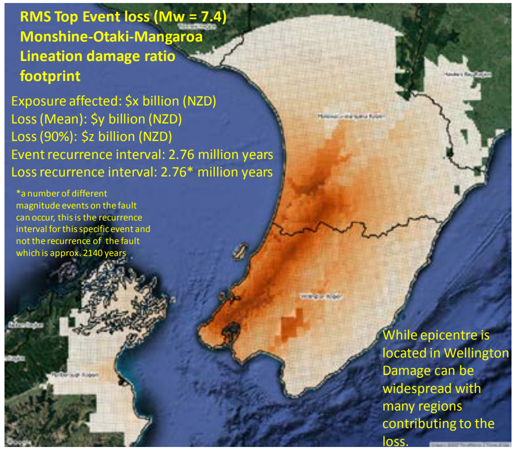
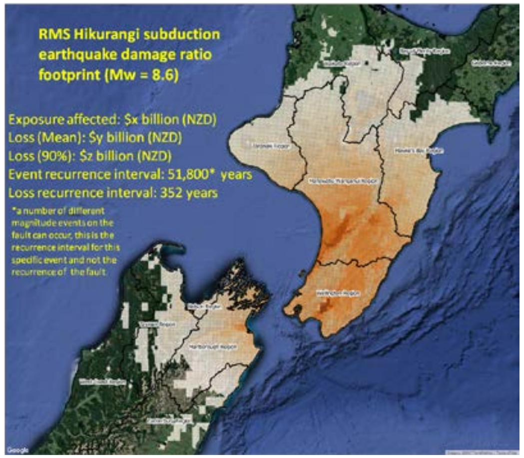
[5] https://www.gns.cri.nz/Home/Learning/Science-Topics/Earthquakes/New-Zealand-Earthquakes/Where-were-NZs-largest-earthquakes

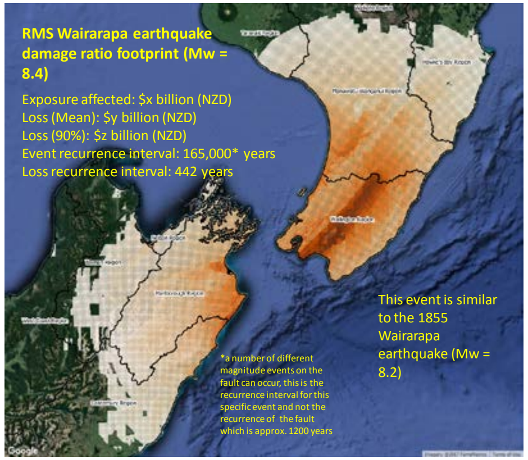
[6] https://www.gns.cri.nz/Home/Learning/Science-Topics/Volcanoes/New-Zealand-Volcanoes/Volcano-Geology-and-Hazards/Auckland-Volcanic-Field-Geology

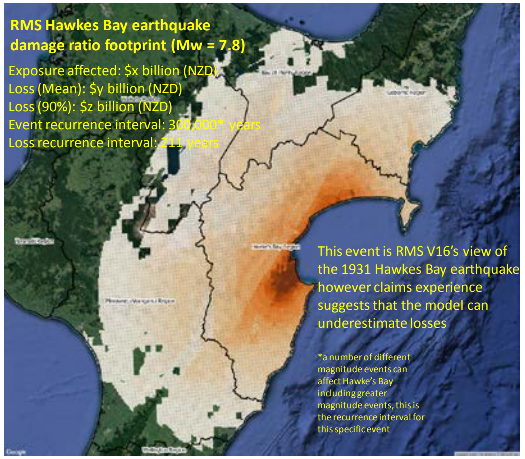
[7] https://www.gns.cri.nz/Home/Learning/Science-Topics/Volcanoes/New-Zealand-Volcanoes

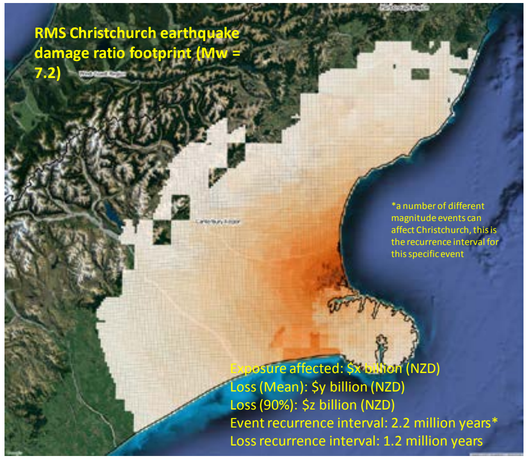
Appendix C Stress Testing Portfolio - Risk Management Solution Catastrophe Modelling

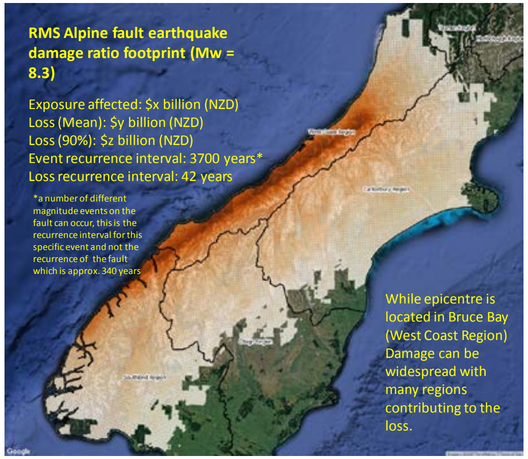






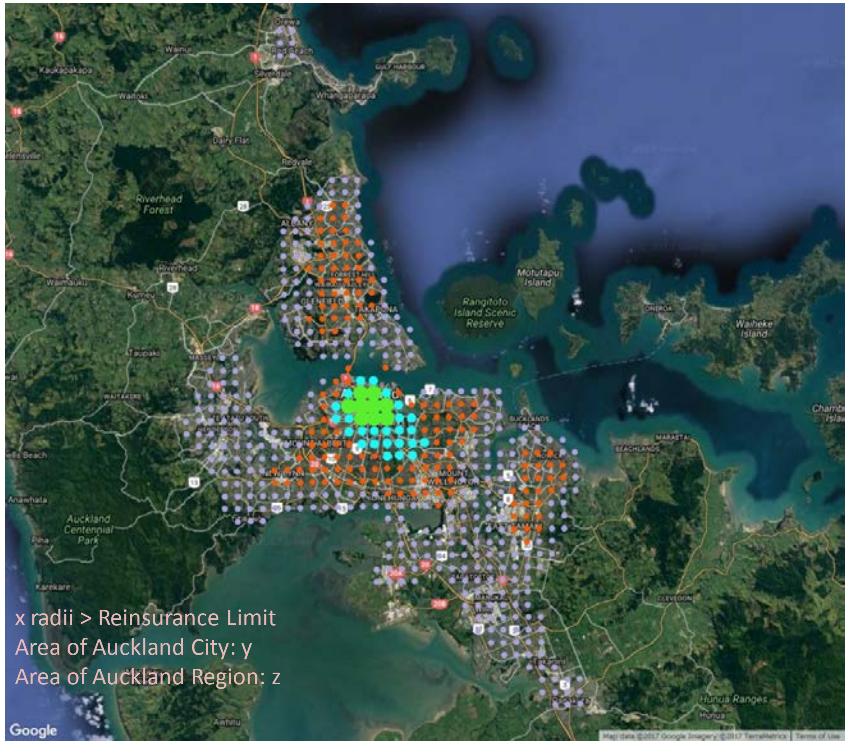




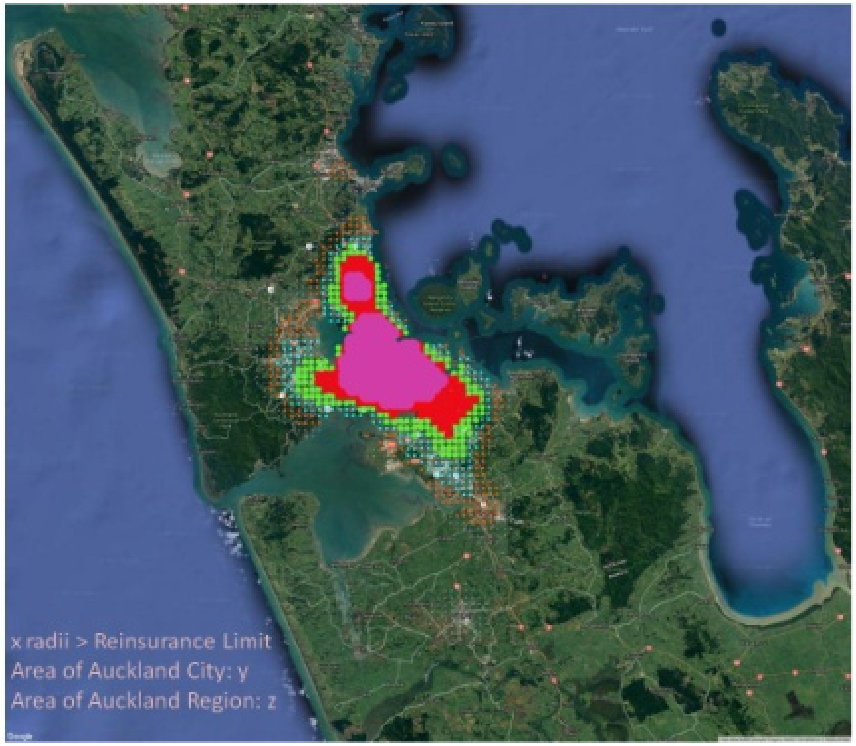


Appendix D Stress Testing Portfolio – Volcanic Modelling

2.5km Radii (Size of Rangitoto)

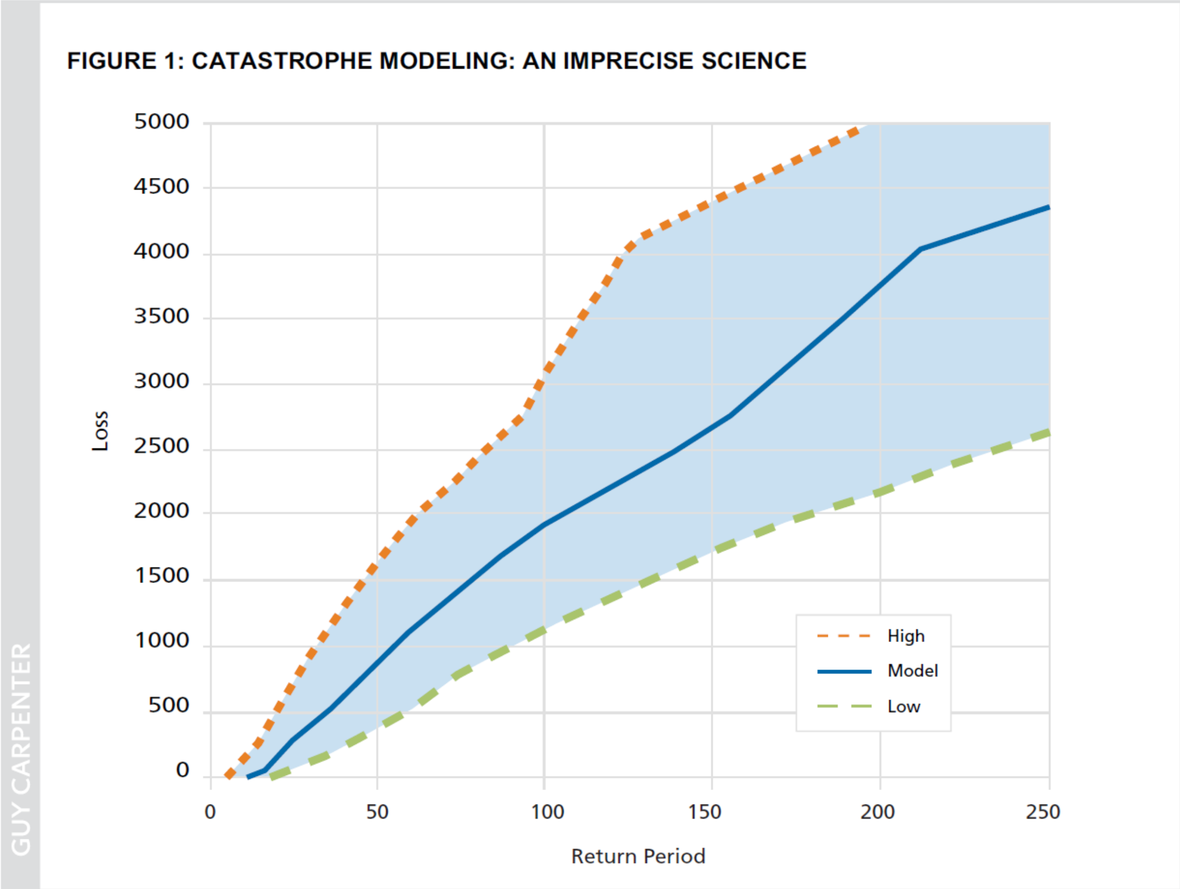


5.0km Radii



The modelling of the impact of a volcano in this paper is rudimentary. It assumed that the gross cost of this event was equal to 100% of the exposure within circular area. The analysis was carried out on two scenarios.

Appendix E Model Uncertainty



Source: RMS and Guy Carpenter

Despite considerable refinement of the models over the decades, uncertainty remains – and it is a significantly bigger factor than many users may recognize. In 1999, Guy Carpenter & Company published estimates of the amount of uncertainty in U.S. hurricane risk models. The conclusion: a two standard error interval (a plausible range that has a 68 percent chance of including the true, but unknown, value) for a national writer's 100 year or higher probable maximum loss (PML) goes from 50 percent to 230 percent of the PML estimate produced by the model.

Advances within the modelling industry since 1999 have indeed reduced the width of the uncertainty band, but the consideration of smaller areas of geography only introduces additional uncertainty.

Extract from 'Managing Catastrophe Model Uncertainty - issues and challenges - December 2011'

Appendix F Historical Events

Alpine Fault[8]

The Alpine Fault, which runs for about 600km up the spine of the South Island, is one of the world's major geological features. It's the "on-land" boundary of the Pacific and Australian Plates.

This fault has ruptured four times in the past 900 years, each time producing an earthquake of about magnitude 8. Approximate rupture dates are 1717AD, 1620 AD, 1450 AD, and 1100 AD. Research, published in 2012, by GNS Science has extended our knowledge of the Alpine fault earthquake record back through the past 8000 years.

Horizontal movement of the Alpine Fault is about 30m per 1000 years - very fast by global standards. Each time it has ruptured, it has also moved vertically, lifting the Southern Alps in the process. In the last 12 million years the Southern Alps have been uplifted by an amazing 20 kilometres, and it is only the fast pace of erosion that has kept their highest point below 4000 metres. The glaciers and rivers have removed the rest of the material and spread it out across the lowland plains or onto the sea floor. The rapid uplift also means that faulted rock from deep down has been brought to the surface, and can be studied by scientists.

The Alpine Fault has a high probability (estimated at 30%) of rupturing in the next 50 years. The rupture will produce one of the biggest earthquakes since European settlement of New Zealand, and it will have a major impact on the lives of many people. In between earthquakes, the Alpine Fault is locked. All these things mean that the Alpine Fault is a globally significant geological structure.

Christchurch

The Christchurch region was hit by a number of earthquakes and aftershocks during 2010 and 2011. Of all the events the three most significant were those that occurred on 4 September 2010, 22 February 2011 and 13 June 2011.

The September earthquake was of magnitude 7.1 on the Richter scale and struck close to the town of Darfield; 40 kilometres west of Christchurch and at a depth of 10 kilometres from the surface.

The February earthquake was magnitude 6.3, lower than the September earthquake. Unfortunately, it struck Lyttleton which was within 10 kilometres of Christchurch and at a shallower depth of 5 kilometres from the surface.

The February earthquake caused 185 deaths, 115 of these deaths followed the collapse of the CTV building. The damage compared to both the September or June earthquakes was more extensive.

The June earthquake was also of magnitude 6.3 but it was located 10 km east of Christchurch and at a depth of 6 kilometres from the surface. It is widely acknowledged that the June earthquake caused damage upon damage.

[8] https://www.gns.cri.nz/gns/Home/Learning/Science-Topics/Earthquakes/Major-Faults-in-New-Zealand/Alpine-Fault

Aside from the three earthquakes discussed above the most notable aftershocks following these occurred on 26 December 2010 and 23 December 2011

The current ICNZ accumulated cost is estimated at $22.288bn[9].

Napier[10]

The 1931 Hawke's Bay earthquake, also known as the Napier earthquake, occurred in New Zealand at 10:47 am on 3 February, killing 256, injuring thousands and devastating the Hawke's Bay region. It remains New Zealand's deadliest natural disaster. Centred 15 km north of Napier, it lasted for two and a half minutes and measured magnitude 7.8 – 7.9. There were 525 aftershocks recorded in the following two weeks, with 597 recorded by the end of February. The main shock could be felt in much of New Zealand, with reliable reports coming in from as far south as Timaru, on the east coast of the South Island.

Nearly all buildings in the central areas of Napier and Hastings were levelled (The Dominion noted that 'Napier as a town has been wiped off the ma'") and the death toll included 161 people in Napier, 93 in Hastings, and two in Wairoa. Thousands more were injured, with over 400 hospitalised.

The local landscape changed dramatically, with the coastal areas around Napier being lifted by around two metres. The most noticeable land change was the uplifting of some 40 square km of sea-bed to become dry land. This included Ahuriri Lagoon, which was lifted more than 2.7 metres and resulted in draining 2230 hectares of the lagoon. Today, this area is the location of Hawkes Bay Airport, housing and industrial developments and farmland.

Within minutes fires broke out in chemist shops in Hastings Street, Napier. The fire brigade almost had the first fire under control when the second broke out in a shop at the back of the Masonic Hotel. The hotel was quickly engulfed in flames. The wind at this point also picked up strength and began blowing from the east, pushing the fires back over the city. With water mains broken, the brigade was unable to save many buildings. Pumping water from Clive Square, they were able to stop the fires spreading south. Only a few buildings in the central Napier area survived. Some withstood the earthquake only to be gutted by fire. Trapped people had to be left to burn as people were unable to free them in time. By Wednesday morning, the main fires were out, but the ruins still smouldered for several days.

Hikurangi Subduction Zone

The Hikurangi fault is where the Pacific tectonic plate is being forced below the Australian subduction zone. Subduction zones are a type of fault and are responsible for the largest and most powerful earthquakes and tsunamis in the world, Sumatra 2004, Chile 2010 and Japan 2011.

Scientists are trying to discover more about this fault but they know that this zone has led in the past to large earthquakes and tsunamis.

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[9] https://www.icnz.org.nz/natural-disasters/cost-of-natural-disasters/
[10] https://en.wikipedia.org/wiki/1931_Hawke%27s_Bay_earthquake

Wairarapa Fault[11]

The 1855 Wairarapa earthquake occurred on 23 January at about 9 p.m., affecting much of the Cook Strait area of New Zealand, including Marlborough in the South Island and Wellington and Wairarapa in the North Island. In Wellington, close to the epicentre, shaking lasted for at least 50 seconds. The moment magnitude is estimated to have been in the range 8.2-8.3, the most powerful recorded in New Zealand since systematic European colonisation began in 1840. This earthquake was associated with the largest observed movement on a strike-slip fault, maximum 18 metres.

Wellington experienced severe shaking but the resulting damage was reduced as the city had been extensively rebuilt following the 1848 Marlborough earthquake using mainly wooden structures; only one recorded fatality (in a brick building) occurred. Reports identify at least another four people (possibly as many as eight) as having died in the surrounding countryside during the earthquake. Numerous landslides were reported along the slopes of the Rimutaka Range. Minor damage was recorded in places as far away as Lyttelton and Christchurch. The uplift of the northwestern side of Wellington Harbour rendered many of the jetties in the harbour unusable, although this new area of land provided a new rail and road route to the north.

Wellington Fault [12]

Although no historic earthquake has been recorded for this fault, the potential impact of rupture along the Wellington-Hutt Valley section on the Wellington area makes it one of the greatest natural hazards in New Zealand. The Wellington Fault is capable of producing earthquakes of up to magnitude 8

Auckland Volcano[13]

Rangitoto was formed by a series of eruptions commencing at least 6000 years ago. The most recent eruptions occurred between 550 and 600 years ago in two episodes, 10 to 50 years apart, and are thought to have lasted for several years during the later shield-forming episode. The first recent episode erupted most of the volcanic ash that mantles neighbouring Motutapu Island, and produced the lower, northern scoria cone. The second episode built most of Rangitoto, erupting all the lava flows and main scoria cone at the apex. The 2.3 cubic kilometres of material that erupted from the volcano was about equal to the combined mass produced by all the previous eruptions in the Auckland volcanic field, which were spread over more than 250,000 years.

In 2013, scientists said new studies showed Rangitoto had been much more active in the past than previously thought, suggesting it had been active on and off for around 1000 years before the final eruptions around 550 years ago. In February 2014, a 150m deep hole was drilled through the western flank of Rangitoto. This revealed a history of activity going back at least 6000 years, with the bulk of activity post-dating 3800 years. Civil Defence officials said the discovery did not make living in Auckland any more dangerous, but did change their view of how an eruption might proceed. The fact that Rangitoto Island has erupted off and on for a long period of time establishes it as the only known

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[11] https://en.wikipedia.org/wiki/1855_Wairarapa_earthquake

[12] https://en.wikipedia.org/wiki/Wellington_Fault

[13] Rangitoto https://en.wikipedia.org/wiki/Rangitoto_Island

polygenetic volcano in the Auckland volcanic field. It is possible that Rangitoto includes a cluster of several small volcanoes that are now covered by the main shield.

References

1 Koob D., Basman J., Britt S., Cohen A., Cooper B., Ferreira D., Tartarwo A., White A (2016) Developing the risk Appetite Framework of a General Insurance Business, Actuaries Institute.

2 Guy Carpenter (2011) Managing Catastrophe Model Uncertainty (Issues and Challenges)