DEVORA
Determining Volcanic Risk in Auckland

Review and Benefit Statement - May 2019
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Front page photo: Simulation of an AVF eruption, created for Exercise Ruaumoko. Image Credit: Jo Horrocks
Executive Summary

DEVORA: making an impact on Auckland’s preparedness for natural hazards

Determining Volcanic Risk in Auckland (DEVORA) is a multi-agency, transdisciplinary collaborative research programme, launched in 2008. Although the primary research focus is the Auckland Volcanic Field (AVF), consideration is also given to disruption from ash fall and gas from distant volcanoes. DEVORA researchers collect and integrate geoscience, volcanic hazard, and risk and social data, with the aim of improving risk management and business decision-making, making Auckland a safer place. The programme is supported by core funding from EQC ($200,000 pa) and Auckland Council ($100,000 pa), and is jointly led by Jan Lindsay (University of Auckland) and Graham Leonard (GNS Science). In addition to the core funding, in-kind co-funding of approximately $300,000 pa is provided by other key institutions, primarily University of Auckland and GNS Science.

The DEVORA programme has garnered international accolades, and has helped boost Auckland’s reputation as a global leader in emergency management planning. In 2016, the Auckland CDEM Group Plan was ranked first in a study of 100 plans from English-speaking cities around the world (Fig. 1). DEVORA’s partnership with Auckland Council underpins and contributes to this success, as preparedness for volcanic hazards was specifically mentioned as one of the reasons for this #1 ranking. In the Global Assessment Report (GAR) on Disaster Risk Reduction 2015 taskforce of the United Nations Office for Disaster Risk Reduction (UNISDR), the DEVORA programme itself was described as a “flagship of integrated natural hazards research and an excellent case study of end-to-end volcanic hazard and risk assessment.”

Auckland, home to over a third of New Zealand’s population, is built on top of the Auckland Volcanic Field (AVF). The AVF covers 360 km² and has over 53 eruptive centres (vents), that have formed over the past 200,000 years (Fig. 2). The most recent eruption, Rangitoto, occurred just 600 years ago. Most vents are monogenetic (i.e. they only erupt once), and most erupt in a new location. This poses a considerable problem for emergency and risk managers, as it is unknown where or when the next eruption will occur, nor how much warning we may get prior to an eruption. Continued research into the AVF will provide the information needed to understand and reduce these uncertainties.

Prior to DEVORA’s inception in 2007, knowledge about the AVF was limited and research was uncoordinated, undertaken on an ad-hoc basis. As such, city planning for a future eruption was not well informed of the potential volcanic hazards or likely risks Aucklanders may face. At that time, only 49 volcanoes were recognized
within the Auckland area, the majority of which were poorly understood. We also knew little about what we might expect from a future Auckland eruption. The DEVORA programme has provided a demonstrable improvement in knowledge about the AVF, with research now undertaken in a coordinated, priority-driven strategy. We now know the precise locations and eruption styles of over 53 volcanic centres and have been able to place 48 of the 53 in relative order of eruption.

Over the last eleven years, we have made great strides in understanding magma rise, precursory signals and warning times, as well as the likely magnitude, style, location and impacts of future dangerous and costly hazards such as pyroclastic surges, lava flows and ash. We now know that explosive eruptions are more likely in certain parts of the city under specific environmental conditions, and we have developed a basic understanding of the distances from potential eruptive vents that need to be evacuated in the event of a crisis. This collective information has allowed DEVORA researchers to develop a series of detailed eruption scenarios spanning the range of eruption styles and possible vent locations. These scenarios have allowed our lifeline partners to model the potential impacts to infrastructure as well as estimate the economic consequences of an eruption in Auckland. The development of RiskScape’s asset database for Auckland is a major DEVORA achievement that enables stakeholders to better assess and plan for potential risks of various natural hazards. Through the RiskScape tool, it is now, for the first time, possible to compare impacts (as well as benefits of different mitigation options) from various hazards, such as volcanic ash fall, tsunami and surface flooding. The body of knowledge generated through DEVORA supports Emergency Management decision making at all stages, from assessing mitigation options (i.e. choosing the most resilient options for major new assets and infrastructure) through to increasing certainty for decision-making around the call for mass evacuation.

DEVORA has a mandate to investigate the geologic underpinnings, volcanic hazards, and risk posed by the AVF and supports Auckland’s growth as an even more sustainable, resilient and liveable city. In this report we highlight the progress of DEVORA over the past eleven years, in particular how DEVORA has unified researchers and stakeholders in a fully integrated framework to address key issues facing Auckland, and how research findings are being implemented into policy and communicated to stakeholders and the public. We will conclude our report by illustrating how the continuation of this regionally and nationally important research programme will contribute to Auckland remaining a global leader in emergency management.

Figure 2. Map showing the locations of the volcanoes and their deposits in the Auckland Volcanic Field.

1Safer Cities of The Future by Canadian researcher Dr. Allan Bonner
DE VORA

ACHIEVEMENTS TO DATE
May 2019

146 media pieces about Auckland Volcanic Field
Raising awareness to the public and decision makers

Over 12,000 resources downloaded online
~328 pieces of research and applied work

>230 Journal articles, reports & other materials
published

4 ‘new’ volcanoes discovered

$300 Million estimated value of data currently in the NZGD

Regular meetings, forums and workshops ensure research is translated, used and focussed on future needs.

32 PhD students
Supporting the next generation of researchers

Researchers 40+ across 11 institutions

Icons made by Freepik/smashicons/vectors market from www.flaticon.com
1. **Determining Volcanic Risk**

There has already been a focus on evaluating the hazard and impacts of possible future eruptions in Auckland.

Researchers supported by DEVORA are collecting more and more data to reach a stage where we can begin to move towards assessing probabilistic risk in Auckland.

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2. **Geophysical Investigations**

We may not know the location and behaviour of all of the AVF eruptions.

Further investigations are required to reduce uncertainty surrounding future activity at AVF.

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3. **Better Monitoring**

We have a suite of new possible monitoring techniques.

The next step is to evaluate the costs and benefits of each to make evidence-backed recommendations to Auckland Council and GeoNet for investments to make Auckland a safer place.

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4. **Lifeline Modelling**

DEVORA researchers plan to collaborate with RNC2 on interdependence modelling for Auckland lifeline resilience.

The scenarios developed in DEVORA provide an excellent foundation.

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5. **Fire Research**

Fires may in fact end up being one of the most challenging hazards we face in the event of a future volcanic eruption in an urban area such as Auckland.

We need more research into the propensity of this hazard, and possible mitigation methods.

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6. **Interdisciplinary Collaboration**

DEVORA researchers plan to continue to collaborate across disciplines and with stakeholders.
Auckland’s Volcano Problem

**Auckland** is vulnerable to volcanic eruptions from the Auckland Volcanic Field (AVF), and DEVORA aims to address this threat. DEVORA research on gas and ash fall impacts is also applicable to eruptions from distal volcanoes, such as Taranaki, Ruapehu, and Ngauruhoe, which historically have erupted more frequently than the AVF. For example, Taranaki CDEM places the Annual Exceedance Probability (AEP) of a Taranaki eruption at 3%. The scope of DEVORA includes assessing the past frequencies and future likelihood of such distal eruptions affecting Auckland.

Within the AVF, the timing and location of future eruptions in the AVF is unknown, however, the last eruption at Rangitoto occurred just ~600 years ago, indicating that the field is still active (Fig. 3). While there is about a 1 in 1000 (0.001 per cent) chance that an eruption could occur in any given year based on averages, this estimate does not properly reflect the potential likelihood of a future eruption in Auckland. DEVORA research has revealed that the time intervals between eruptions is highly variable, with repose periods ranging from hundreds of years to tens of thousands of years. Future eruptions are likely to expose Auckland to several hazards, including explosive base surges, lava flows, volcanic tsunami, ballistic ejecta and widespread volcanic gas and ash, and knock-on hazards such as fire (Fig. 4).

> **Figure 3.** DEVORA Fact Sheet #1 provides an introduction to the Auckland Volcanic Field. [http://www.devora.org.nz/download/1063/](http://www.devora.org.nz/download/1063/)

> See full version in the Appendix.

**Impacts from volcanic activity could include but are not limited to:**

- Devastation of buildings and infrastructure within a 1-6km radius of the volcanic vent or within the direct path of lava flows, which in past eruptions have travelled up to 11 km from the vent.

- Large economic losses due to clean-up costs, physical damage to buildings and infrastructure, prolonged exclusion zones due to ongoing activity, uncertainty over when it is ‘over’, life safety and service restoration times, closure of businesses, damage to horticultural and agricultural products and a decline in the region’s tourism and GDP.

- An increased risk of widespread fires from hot ash and/or lava disrupting gas supply lines.

- Disruption and restrictions to lifeline networks such as electricity, gas and water supplies, and waste, stormwater and transportation networks from any of the hazards mentioned above.
• Ash and dust will affect air-conditioning systems and may cause significant disruption to both primary power supplies and back-up generators, along with any systems that rely on electricity (including for example water supplies).

• Road networks within a 10km radius of the vent may be impassable or greatly affected.

• Rail and air services either halted or greatly reduced.

• Eye and lung irritation and poor sanitation causing increased health risk.

![Image](image_url)

Figure 4. Artist’s impression of a hypothetical AVF eruption in shallow waters of the Manukau Harbour. Image credit Jo Horrocks.

**Knowledge** of the inner workings of the AVF, the likely hazards, and the impacts of an eruption have been greatly improved by DEVORA researchers, however, critical uncertainties and areas for further study remain. It is unclear how much advance notice we will get of an impending eruption or the subsequent evacuation radius and location. Some notice (on the order of hours to weeks) from precursory signs such as small-scale seismic activity or gas level changes is expected but is not guaranteed. These early warning signs may provide time for a controlled evacuation of the affected population, however, uncertainty in the warning time remains high. Improved hazard models will best mitigate the risk by providing a better understanding of the required evacuation extent. Understanding both the potential warning times and the likely eruption hazards allows us to reduce life risk and avoid over-conservative evacuations (too early or too large) which could have major adverse economic and social consequences. At this stage, our understanding of potential damage to infrastructure is limited, hampering our ability to develop useful recovery plans. The ability to improve resilience through design is also being missed.
Some of the key questions that DEVORA has worked to better understand over the last 11 years include:

● What is the likelihood, impact and consequent risk of a future eruption in time and space?
● What precursory geophysical and geochemical signs might we see prior to an eruption?
● What are the opportunities to improve our monitoring network and warning measures?
● How much warning will these provide, and how much certainty is attached?
● How can we best assess the area needed to be evacuated?
● What is the vulnerability of Auckland’s infrastructure to volcanic hazards, and what type and degree of damage will likely be caused by a volcanic eruption?
● What will the economic impacts of a volcanic eruption be?
● How and when can we best recover from an AVF eruption?
● How can we best communicate volcanic risk and support decision making?

By answering these and other questions, we can achieve the 10 aspirational outcomes for DEVORA:

1. We are confident in knowing the Auckland Volcanic Field (AVF).
2. Our diverse society knows, understands and trusts our science.
3. People will behave appropriately in a volcanic crisis.
4. People have access to risk and consequence information in formats that suit their needs.
5. Auckland Council, Businesses and individuals have anticipated, prepared for and are able to respond to and recover from a volcanic eruption (i.e. planning is appropriate).
6. DEVORA supports sustainable development and expansion of a 'Resilient Auckland'.
7. Auckland continues to thrive following any NZ eruption.
8. Our science is well managed and has wider benefits.
9. Auckland is linked into other major hazard programmes through alignment with DEVORA.
10. We are confident in knowing other volcanic threats to Auckland.
DEVORA: Achieving Results

This section highlights major achievements of DEVORA in the past 11 years, specifically addressing the knowledge we have delivered on a number of topics. We explain how we estimate eruption frequencies and consequently, the likelihood of future eruptions and the strides we have made in understanding Auckland’s youngest volcano, Rangitoto, and what its odd behaviour could mean for future AVF eruptions. We also explain how we have characterised the magma sources feeding Auckland’s volcanoes, are investigating how fast this magma ascends, how we will detect and monitor the field for rising magma, and, more critically, what this information tells us about how long we will likely have to warn the public. We are especially proud to highlight the completion of eight AVF eruption scenarios, which cover a full range of likely environmental settings/locations, sizes, and hazards that may occur during a future eruption. As we are not able to predict location with any certainty, the scenarios make it possible for more complete evacuation and recovery planning to occur, and allow us to provide detailed, quantitative descriptions of impacts to Auckland from a volcanic eruption.

Alongside our research contributions, DEVORA works to foster and strengthen relationships that are key for hazard and risk planning in Auckland, both in peacetime and during an eruption crisis: with stakeholders, media and the public. We describe below how, at every stage of the research process, we consult with our partners, particularly the Auckland Lifelines Group / Volcanic Impact Study Group, Auckland Council, and Auckland Emergency Management, to help shape our research directions and prioritise stakeholder needs. We also detail our public good outreach efforts, how we work to educate the public about Auckland’s hazards, as well as highlighting our key collaborators and strategic partnerships, such as between Auckland Council and the University of Auckland.
Likelihood

Problem statement

To make predictive models of the AVF, we need to understand the frequency and sequencing of past eruptions. To determine the sequence of events, however, we have to have well constrained ages on as many eruptions as possible. Armed with this information, scientists can check for patterns in the timing, location, and volume of past volcanic activity and gain an understanding of what can be expected in the future.

Tephra and gases from distal eruptions, such as those at the Central North Island volcanoes, can be carried by the wind and cause disruptions in Auckland. As an example, ash fall from the 1995-96 Ruapehu eruption caused the Auckland airport to close for a short period of time and was very costly the New Zealand economy. It is important to understand the amount of ash fall and/or volcanic gases that could reach Auckland from eruptions elsewhere, and how often this occurs, in order to properly prepare for and mitigate these threats.

DEVORA contributions to date

A major success story from DEVORA is its radiometric and tephrochronological dating programme (Fig. 5). The ongoing dating initiative endeavours to date lava and carbon material from previously undated or poorly dated centers, and thus helps to increase our understanding of the sequence of AVF eruptive activity. To date, 35 of the ~53 volcanic centres of the AVF have been directly dated, 23 by the DEVORA programme. The number of dated volcanoes has been further raised through DEVORA to 48 by correlating volcanoes to ash layers in lakes, making the AVF one of the most well-dated volcanic fields in the world. Where samples are not viable for radiocarbon or radiometric dating, paleomagnetic work and relational stratigraphy provide other methods for constraining the eruption age. By studying the chronology of the eruptions, eruption frequencies can also be examined. This analysis revealed an increase in the number of eruptions starting ~60,000 years ago. Figure 6 shows this increase, discovered as part of the DEVORA programme, and the complex tempo of eruptions since 60,000 years ago.

Through DEVORA, we have found out that AVF eruptions and distal ash fall events occur more frequently and their hazards are potentially more devastating than previously thought. By drilling sediment cores from numerous explosion craters around Auckland, DEVORA researchers have extracted a record of the number, frequency and thickness of ash deposits (Fig. 5). This tells us how often Auckland has been impacted by falling ash in the past. To date, seven explosion craters (or maars) have been drilled and studied. This tephrochronology work has revealed that, on average, Auckland is impacted by an ash fall event at least once every 420 years, with Mount Taranaki being the most frequent contributor. This number is nearly double the pre-DEVORA estimates. This work is on-going, as we continually work to improve our database of recorded eruptions in Auckland.
Figure 6. Auckland volcanoes ordered in eruptive sequence by their ages using three approaches: (a) only volcanoes with radiometric dates, with annotation describing the complex tempo of post 60 ka eruptions; (b) undated volcanoes are placed at their oldest possible position; (c) undated volcanoes are given their place in the eruptive sequence by the youngest possible age.
Rangitoto research

Problem statement

As the largest, youngest, and most geochemically diverse volcano in the field, Rangitoto is an anomaly in the AVF. Evidence also suggests that it is long-lived with multiple eruptions occurring over a significant time period. This departure from the norm makes it more difficult to forecast potential future activity in the field and indicates that our current understanding of monogenetic volcanism requires further refining.

DEVORA contributions to date

Research through DEVORA has investigated in detail the geochemistry of the lavas and tephra on Rangitoto to reveal that it formed during two eruptions, with radiocarbon age dating suggesting these may have occurred a few decades apart, approximately 650 - 600 years ago. In order to try and get better constraints on the eruption history of Rangitoto, a 180m hole was drilled into the side of the volcano in 2014 (Fig. 7). The age of shells and other materials uncovered at the base of the drill core led some researchers to believe that the volcano erupted intermittently for 6,000 years, however, other scientists refute this finding and point to obvious areas of reworking and churning of the original sea floor by explosive eruptions and/or lava flows elsewhere on Rangitoto that could render this dated material as unreliable.

Current DEVORA research on Rangitoto is focused on gathering as much age data as possible from the volcano to solve this conundrum. Select lavas in the core have been analysed for radioactive elements, and the data reveals that it is very unlikely that they erupted several thousand years apart. Palaeomagnetic signals in the drill core lavas are being analysed for likely ages, as well. In a recent study, DEVORA researchers analysed volcanic material from Rangitoto on nearby Motutapu Island. The characteristics of these deposits are indicative of an emergent, initial phase of volcanism and have been conclusively dated at ~650 years ago, lending support to the idea that eruptions at Rangitoto have been limited to a period of activity 600 – 650 years ago.
Magma Ascent, detection and monitoring

Problem statement

In order to create appropriate monitoring and warning systems, we need to understand the nature of the crust beneath Auckland and how quickly magma might travel through it. Understanding crustal-magmatic interactions in the context of warning time is influenced by several factors:

Detailed knowledge of the crustal structure
When magma moves through crust, it is potentially channelled to the surface through weak points (e.g. faults). Thus it is important to map potential fault locations. This also increases knowledge of Auckland’s seismic hazards and our understanding of the general stress field of the Auckland region, which was identified as one of the top hazards to the Auckland region in the Auckland Civil Defence and Emergency Management Group Plan. We can also get a better handle on crustal structure through geophysical and modelling studies.

The sensitivity and coverage of seismic monitoring techniques
In Auckland, local small-scale earthquakes will likely be our first warning of an impending volcanic event. Starting at ~30-40 km depths, the more flexible mantle transitions into brittle crust, which rising magma must break through to get to the surface. As the magma breaks through the crust, it creates earthquakes. To ensure that emergency managers have as much warning as possible prior to the event, it is critical that Auckland have state-of-the-art monitoring to detect these earthquakes as early as possible.

Understanding magma properties, behaviour, and ascent through the crust
Several factors may affect how quickly magma can ascend through the crust and reach the surface (e.g. depth of the magma, properties of the magma, structure of the crust), and it is therefore important to understand these factors. Rock properties (e.g. crystal and bubble content, geochemistry) and depth of the magma source can be estimated by looking at samples of already-erupted material (volcanic rock).

DEVORA contributions to date

DEVORA researchers have collated a geochemical database for the Auckland Volcanic Field, with 50 of the 53 volcanic centres represented in the database. This allows researchers to carefully deconstruct the patterns, mechanisms, and mantle sources feeding Auckland volcanoes.

Through thorough detailed geochemical analysis of several volcanoes, combined with the geochemical database, DEVORA researchers have revealed that there are likely three sources of magma in the mantle underneath Auckland, which may mix as the magma rises. One to two sources (fertile asthenospheric mantle, carbonated rock or eclogite) originate approximately 80-100 km below the surface. An inferred region of partially molten rock at this depth can be seen in an image created using seismic tomography in 2006, suggesting that the deep source is primed and waiting for an ascent trigger (Fig. 8). Melt from the third source
(subduction metasomatised lithosphere) originates at a shallower depth, melts in greater volumes, and thus far has only been found in the larger eruptions in Auckland, such as Rangitoto. Melting of this shallower mantle source is potentially triggered by the rise of the deeper melt, though chemical evidence suggests that this occurs only occasionally. We now have evidence that the size of the resulting volcano is controlled by the geochemistry of the mantle source.

![Seismic imaging of Auckland's subsurface](https://www.tandfonline.com/doi/abs/10.1080/00288300709509814)

Figure 8. Seismic imaging of Auckland’s subsurface may have revealed a region of partially molten rock ~80 km underneath the city. Image credit: Horspool et al., 2006.

We now know that each mantle source has a unique chemical signature, and these chemical properties may affect how fast the magma rises, especially from shallow depths where we are likeliest to get the first warning signs (Fig. 9). Geochemical evidence from multiple studies points to a quick ascent, but prior to DEVORA, there was only one theoretical study, which estimated that Auckland magmas take between 5 hours and 5 weeks to ascend from a depth of ~100 km. In a more recent DEVORA-affiliated study, researchers measured concentrations of water trapped within crystals brought up with AVF magmas from depths between 27 and 80 km. They suggest that Auckland magmas stall in multiple places below the crust and the magma rises in stages, with storage times between one month and several years. Their data indicate that ascent from the base of the lithosphere (~50 km depth) takes weeks to up to a month, correlating to an expected 1-2 weeks of warning time after precursory earthquakes start.

More research in this area is needed to refine estimates of warning time, particularly from shallow depths, where precursory
signals are expected to begin, i.e., magma-related earthquakes breaking up the shallow crust starting at < 30-40 km depths. One ongoing study is measuring volcanic gases in magma partially trapped in crystals that formed < 30 km from the surface and then erupted. The depths that this study covers aligns well with the depths we are interested in for ascent. Thus far, data from this study reveal unexpectedly high water and CO₂ concentrations in Auckland mantle sources, which should act to propel magma to the surface quickly. Data will be fed into a geochemical diffusion model, which, coupled with depth estimations, will allow researchers to estimate magma ascent rates through the shallow crust and provide warning times. Yet another researcher is using the properties of magma (e.g. viscosity) to create a model of rising basaltic melt through Auckland’s crust.

An example of a great indirect achievement that arose from DEVORA’s work to improve our understanding of the crust is the development of New Zealand Geotechnical Database (NZGD). In the early years of DEVORA, we funded and managed the development of the DEVORA borehole database, which collated geotechnical data from sites across Auckland. This data was used in a number of projects, including: evaluating the distribution of tephra across the region, ground truthing geophysical studies, and revealing approximately 63 hidden faults in Auckland. After the Christchurch earthquakes, the DEVORA borehole database was merged with the Canterbury borehole database to form the foundation of the NZGD, which has since grown to include data from across the country. This is a major achievement given that most of the datasets were proprietary and confidential prior to the development of the database. It has been estimated that the data in the NZGD is worth > $300 Million, and that the platform has saved $1-5M in drilling costs through the ability to access such shared data. As many of DEVORA’s scientific endeavours depend on understanding the make-up and structural elements of the crust, this dataset is extremely important. The GNS Urban Mapping Project will be re-mapping Auckland’s geology in the coming years and will rely heavily on the DEVORA contribution to the NZGD. Compatible datasets and regular communications will maximise the value of this data sharing. Current ongoing work aims to model Auckland’s crustal structure by applying innovative seismic noise tomography techniques suited to busy urban environments like Auckland; ground-truthing such studies with borehole data is critical.

DEVORA is currently exploring the benefits in terms of earlier detection and more accurate forecasting of a range of potential emerging monitoring tools. These include novel and emerging geophysical, geodetic and geochemical techniques. This work will contribute to the vision for our monitoring network into the future. By combining this knowledge described above—crustal structure, fault locations, magma behaviour and ascent—with more sensitive instrumentation and eruption precursor warning signs such as seismicity related to magma movement, DEVORA can potentially estimate how much time it will take for the magma to travel to the surface, perhaps identify the faults it may travel through to help narrow down potential vent locations, and improve lead times prior to an eruption.
Evacuation and recovery planning: DEVORA scenarios

Problem statement

In the event of volcanic unrest and eruption in Auckland, emergency managers will make several major decisions such as when to evacuate, when to return, how best to mitigate the impacts of and recover from the event. There is also a need to describe the diversity of credible (sometimes prolonged and complex) eruption sequences, hazards and impacts across Auckland, to support planning and decision-making.

DEVORA contributions to date

DEVORA supports Auckland Emergency Management to prepare for these decisions by providing expert information and tools that will provide justifications for decisions during post-event evaluations. We also work to understand the various issues with mass evacuation in different parts of the city. A key achievement in this area has been the DEVORA study that focussed on how GIS might be used to support evacuation decisions in the event of an AVF eruption. A current project underway involves evaluating how hazard, risk and cost-benefit analysis may be integrated into a decision support tool for Auckland EM. This work is being carried out in close collaboration with Auckland EM and other stakeholders. Indeed, DEVORA scientists have been identified as subject matter experts for the Auckland Civil Defence and Emergency Management Group to call on in times of volcanic crisis.

DEVORA researchers have begun volcano disaster waste management and planning in Auckland. Volcanic ash is one of the most widespread volcanic hazards associated with eruptions. Due to its hazardous effects on health and lifelines such as power lines and water supply, the clean-up, disposal, and stabilisation of volcanic ash is often considered a priority during and after eruptions. Studies of eruptions in other urban areas indicate that clean-up efforts are costly and require advanced planning to identify collection and trucking routes, disposal areas, and strategies to prevent ash from remobilising. With Auckland Council, researchers have scoped appropriate routes to open landscapes in Auckland that may be used during ash collection.

Following on from these findings, a further study focuses on reuse and stability of pyroclastic deposits in a post-eruption Auckland, these studies demonstrate our holistic approach to disaster risk reduction for Auckland Volcanic Risk, with our increasing focus on informing post-event recovery.

In order to aid planning for an Auckland eruption, DEVORA has created eight representative scenarios. The scenarios cover a range of eruption styles and sizes and are tailored to certain environmental conditions (seawater, hard rock, partially-saturated ground, etc.). Each of these scenarios draw on the latest domestic and international research to portray credible hazards and hazard intensities given various substrates and magma volumes, and their corresponding eruption styles and eruption sizes. These have been co-produced by scientists, Emergency Managers and representatives from lifeline organisations to create a product representing a common language between scientists and stakeholders. These scenarios are a complimentary approach to probabilistic and risk-based approaches.
Impacts to Auckland

Problem statement

If an AVF eruption were to occur, it would have a significant impact not just on the city’s population but also on its infrastructure. This includes possible impacts of 13 distinct but interconnected hazards: ash fall, Pyroclastic Density Currents (PDCs, hot fast moving ash clouds), lava flows, ballistics (flying hot rocks) edifice formation (new mountain or lake), earthquakes, ground deformation, volcanic lightning, gas emission, acid rain, tsunamis, localised flooding (lahars) caused by ash and debris, and fire caused by eruption. As the possible impacts are identified and quantified, researchers work with stakeholders to mitigate impacts and target and refine new research priorities.

DEVORA contributions to date

DEVORA has made many contributions to better understanding possible volcanic impacts in Auckland.

The research team includes all of New Zealand’s globally-leading volcanic impact scientists across three Universities and GNS Science, 11 institutions in total.

DEVORA supports collaborative projects with researchers in areas that have experienced volcanic unrest or eruption similar to what is expected in Auckland, to gain insight into possible impacts. Scientists and emergency managers from such locales have experienced the impacts of volcanic events in real-time and thus can provide valuable information on lessons-learned and identify workable solutions that can be applied in Auckland.

Such studies have greatly increased our working knowledge of the potential effects of a volcanic eruption. However, without accurate information on the infrastructure that might be affected (i.e. buildings, roads, electricity grids, etc), it is not possible for scientists to create a realistic scenario of the extent of what will happen. Therefore, specific information about

Figure 10. Poster describing the effects of volcanic ash fall on water supply, with suggested mitigation solutions for water supply managers. This poster is one in a series of ash impact posters developed by the Volcanic Impacts Study Group with support and findings from DEVORA. See full version in the Appendix.
Auckland’s assets and vulnerable infrastructure is needed to model potential effects of an eruption on Auckland. Over the last eleven years, DEVORA researchers have worked with lifelines (electricity, airport, transport, telecommunications, banks, etc.) to incorporate network structures and assets into the RiskScape tool, which allows estimations of impacts and damage in specific scenarios. Researchers also work to examine possible impacts in laboratory settings and use their findings to generate mitigation solutions for lifelines organisations. Volcanic impact data derived over DEVORA’s research programme have been summarised in a series of posters describing ash fall impacts on infrastructure (Fig. 10).

Volcanic eruptions vary in their size, force, and possible impacts. Therefore, it is important to understand the potential hazards and create models that cover a range of eruption scenarios and styles. Such models can be used for planning purposes and help to mitigate potential impacts. DEVORA has put significant effort into evaluating various hazard models (i.e. ash-fall, lava flow, PDC) and modifying them to match known AVF characteristics. In the long term, these models will be integrated into Riskscape to enable increasingly accurate estimations of impact.

The nature of the shallow crust greatly affects the style of eruption, particularly in areas where water is stored in the substrate. This has implications for potential hazards and it is a major constraint on the level of explosivity involved in a potential eruption. Moreover, eruptions are shown to have multiple phases, which have variable hazards. If we can determine what style to expect, we can predict what hazards are likely to occur. This matters for planning purposes as some hazards are more dangerous than others.

This is important because in the event of an AVF eruption, the city’s infrastructure will be vulnerable to a variety of hazards. Some infrastructure, such as buildings, will be more affected by the vent effects, while others such as the electricity grid will be more impacted by the widespread hazard of ash-fall. To mitigate such impacts, we create fragility functions, which relate for a particular asset, the level of damage to level of hazard, and which can identify the threshold of impact that can be sustained without permanent loss of functionality. DEVORA tests the various damage thresholds of materials via analogue modelling, laboratory experiments, historical examples, and expert judgement. They then create fragility functions that can be used in Riskscape.

The next AVF eruption can happen at any location within the current field boundaries, can vary in size and eruption style, and can produce a range of hazards. This makes it particularly challenging to forecast impacts or effects of eruptions on the city. We have identified that in this case, eruption scenarios can be an effective way of conveying eruption complexities, exploring consequences, and generating fruitful discussions and awareness building with stakeholders. As mentioned earlier, DEVORA researchers have created eight eruption scenarios that cover a range of eruption styles and sizes and are tailored to certain environmental conditions (seawater, hard rock, partially saturated ground, etc.). Each of the eight scenarios is carefully constructed to portray realistic hazards and hazard intensities given various substrates and magma volumes and their corresponding eruption styles and eruption sizes. We have carried out a detailed impact assessment using one of these scenarios, the Mangere Bridge Scenario. Results from this evaluation revealed significant impact on Auckland. An eruption in this location would lead to power being cut to Northland for months, severe water shortages in Auckland for a year, Auckland airport would be closed for 2-3 months, 100,000 people will be displaced, 11,000 others will be left homeless, and raw sewage will be discharged into both harbours for 2-3 years. Understanding the impacts of a specific scenario allows researchers and practitioners to develop appropriate plans for preparing for, managing and recovering from an eruption.
Collaboration: Outreach and stakeholder engagement– sharing our knowledge of Auckland’s Volcanoes

Problem statement

Approximately 1.7 million people live atop the Auckland Volcanic Field and are exposed to a variety of different hazards, ranging from common events such as storms to rare events such as volcanic eruptions. Our scientific understanding of hazards in the Auckland region increases constantly. Therefore, it is important that the science be communicated with relevant stakeholders, including the public, in an understandable, useable format. Stakeholders include Auckland Emergency Management and various lifeline groups, all of whom need scientific knowledge in order to identify vulnerabilities and to prepare for future volcanic activity. Through the DEVORA programme, a strong partnership has developed between Auckland University and Auckland Council, which has, in recent years, also expanded to include other natural hazards (e.g. landslides and seismic hazard). This is a strategically important relationship, not only to ensure Auckland develops as a resilient city but also because the University of Auckland supplies many graduates to Auckland Council.

DEVORA contributions to date

DEVORA is involved in a variety of communication approaches. DEVORA has appointed an Outreach Coordinator who works to communicate our science to the public via various outreach events and by engaging with schools, museums, and other local community organisations, to develop new linkages, and strengthen and maintain existing relationships. Thus far, 124 outreach engagements with Auckland’s public have taken place through DEVORA efforts, and DEVORA research has appeared in nearly 150 TV news segments, newspaper articles, radio shows, and other press. DEVORA works to communicate our science through a series of Fact Sheets, shown in this report, as well as tangible educational products such as signage and museum displays. We prepare press releases about DEVORA research when key publications of interest come out.

We also share our research findings with various stakeholders through participatory workshops and role-playing eruption simulations. The mock eruption exercises emphasise how valuable established relationships between scientists, emergency managers, and lifelines would be when faced with the immediate deadlines and intense

![DEVORA outputs](image_url)
pressures of an eruption crisis. The scientific knowledge coming out of DEVORA informs the action plans of Auckland Emergency Management and various lifelines groups, thus influencing the ability of Auckland City to prepare for and respond to a local volcanic eruption (or ash from a distant eruption).

**Stakeholder engagement**

Stakeholder engagement is critical to the mission of the DEVORA research programme; the science must have societal relevance towards preparing for and responding to volcanic activity in Auckland. To this end, we are involved with multiple strategic partnerships in order to maximise the practical application of research that has emerged from DEVORA scientists.

Our primary partner is Auckland Council (AC). Within AC we have worked with Auckland Emergency Management (formerly called Auckland Civil Defence and Emergency Management), Planning and Intelligence, and the Research and Evaluation Unit (RIMU) and the Tūpuna Maunga Authority. Auckland Emergency Management (AEM) and RIMU have representation on the DEVORA steering committee, and we actively engage with each other in terms of the best ways to tailor DEVORA research for AEM and other planning. An example of engagement with AC is a workshop led by DEVORA in 2018 that involved 20 AC staff members, and was aimed at familiarising them with volcanic hazard and risk in the Auckland Volcanic Field.

DEVORA has been working with the Auckland Lifelines Group since the beginning of the programme, recognising that Auckland’s level of resilience in a volcanic event will depend on the functionality of lifelines, including utilities and transportation. Over time, we have also developed relationships with emergency responders (Fire and Emergency NZ and NZ Police), as well as insurance companies. We are building a relationship with local iwi and the Tūpuna Maunga Authority in an effort to reach deeper into Auckland’s communities.

**Public engagement**

The most prominent form of public engagement is through the media, including interviews and appearances in documentary films, television (documentaries and news), radio, and print. At a face-to-face level, the DEVORA outreach group engages with the public in a variety of ways depending on the age and experience of the target audience and the purpose of the event (Fig. 10). We reach the largest numbers of people through working with other organisations and participating in events that up to a few thousand people attend, for example the Auckland Heritage Festival and MOTAT open days. We also work with smaller organisations, groups and schools doing demonstrations and teaching, giving talks, and leading field trips.

**Media engagement**

DEVORA researchers and students have made it a high priority to engage with the media to share the results of their research with the public. We put out press releases whenever key pieces of new research are published, and have formed relationships with journalists in order to make sure that our message is communicated accurately. Several DEVORA researchers have participated in courses (e.g. Science Media SAVVY at the Science Media Centre) to develop good media communications skills. We have developed a Communications and Media Strategy for the DEVORA programme which outlines communication pathways to ensure researchers and our partners are not caught unawares of media attention. We have created a ‘media alert’ system for research that may be potentially alarming, or for when the media calls unexpectedly, which allows us to notify our partners, provide them with the necessary information, and help them prepare, prior to media attention.
We have done ~150 interviews that have appeared in film, on television, on radio, and in both online and printed press. We also put out a series of fact sheets, each of which describes an element of volcanism in the Auckland Volcanic Field. These are distributed at outreach events and available online.

Large-scale face-to-face engagement (100's to 1000's of attendees per event and 8-12 DEVORA volunteers)

In these events we do a series of volcano-related demonstrations and experiments that get children (and their guardians) excited about volcano science and teach them how volcanoes work. An example is using the popular Diet Coke and Mentos demonstration to illustrate how a bottle of Diet Coke is like a magma chamber; when a tube of Mentos is dropped in the coke, the resulting burst of bubbles in the “magma” triggers an explosive eruption.

The DEVORA outreach group has participated in large events at Auckland’s major museums, the University of Auckland, and Middlemore Hospital and has thus interacted with many thousands of members of the public. The large museums where we have done multiple outreach events are the Auckland War Memorial Museum, the Museum of Transport and Technology (MOTAT), and the Stardome Observatory (Fig. 11).

For large events, we have started collaborating with QuakeCORE, whose volunteers work side by side the DEVORA volunteers and teach about earthquake engineering. This increases our profile and draws more people in than might otherwise engage.

Smaller-scale face-to-face engagement (10's to 100's of attendees per event and 1-2 DEVORA volunteers)

DEVORA researchers and students have given talks, made classroom visits, and led field trips for dozens of schools and organisations. School visits for younger children include doing demonstrations as described above in classrooms or for entire year groups. For older students and groups such as the U3A or local organisations, we give talks about specific subjects, e.g. the Auckland Volcanic Field or volcanic hazard in Auckland.
We have led dozens of field trips to Rangitoto and around the Auckland Volcanic Field for schools, and also for academic conferences, including volcanologists, mineralogists, and earthquake engineers.

Role play volcanic eruption simulations
As part of our education, outreach, and training mission, DEVORA has run two variations of a role-play exercise in which a volcanic eruption in Auckland unfolds and the participating group has to cope with the initial unrest through the impacts of the eruption. Each year a simulation is included in the postgraduate Geohazards course at the University of Auckland. The simulation is a full-day exercise, in which the 30-40 students meet in the Emergency Control Centre at Auckland Emergency Management (AEM) and take on roles of emergency managers and geologists (Fig. 12). The groups need to work together to address the events of the eruption and protect the people of Auckland. We also have run a similar scenario with actual geologists from GNS Science and emergency managers from AEM. The exercise exposes participants to a realistic enough experience and teaches them the importance of communication within and between the groups, as well as the limitations of our understanding of an eruption scenario and the necessity of making critical decisions with limited knowledge. It is excellent training for both professionals and students who may be interested in a related career.

Figure 12. An Auckland Eruption Simulation is held each year in Auckland Emergency Management’s Emergency Coordination Centre. University of Auckland postgraduate students play the roles of geoscientists, emergency managers, and media as an eruption plays out over the course of the day.
Annual Research Forum and Steering Committee

Problem statement

If researchers are not informed of ongoing work, they may duplicate studies. This is not only a waste of time and money, but can also cause conflicts and distrust. Also, if we do research without some degree of co-creation of a research plan with stakeholders, we may deliver results that do not meet their specific needs. Additionally, in the event of eruption precursors, volcanologists, civil defence, and lifeline representatives would all have to mobilize and communicate succinctly under intense pressure and immediate deadlines. This will require understanding one another’s needs, perspectives, and communication styles.

DEVORA contributions to date

Since its inception, fostering linkages between scientists and those that would be involved in a volcanic crisis and its aftermath (e.g. emergency management, lifelines organisations, physical and social scientists, and other critical stakeholders) has been a crucial part of DEVORA’s work plan. DEVORA efforts ensure that these linkages and relationships are created well in advance of any emergency, and potentially provide value for other hazard mitigation programmes as well, as DEVORA researchers are intimately linked to tsunami, seismic, and other hazard and risk research programmes.

These linkages are created, maintained, and strengthened through a variety of means. DEVORA hosts a number of meetings, workshops, and other events with multiple organisations, from lifelines to EM to scientists in various areas of expertise. We meet regularly with stakeholders and DEVORA and other AVF researchers to align research and discuss priority research needs. The main avenue for doing this is the annual research forum, which occurs around November every year and provides an opportunity to bring together researchers and research stakeholders, to discuss the year’s most interesting findings and also to identify any gaps in our research programme and identify key priorities for the coming year (Fig. 13). Forum attendance has grown from ~40 people in early years to over 90 in the most recent forum, with representatives from a variety of EM, lifelines, scientific organisations, and other stakeholders from across New Zealand.

Figure 13. Scientists, emergency managers, lifelines, and others connect and get informed about latest AVF research findings at our annual DEVORA Research Forums.
Zealand. We have successfully co-hosted our annual research forum with Auckland Council and Auckland Emergency Management twice. DEVORA also contributes to Auckland Lifelines Group’s Volcanic Impact Study Group (VISG) seminars and has an appointed liaison. In addition to these meetings, DEVORA researchers and leaders remain in close contact with AEM, EQC, and lifelines representatives through informal channels, such as email, phone calls, quarterly progress reports, etc.

The DEVORA Steering Committee meets once every six months. The meetings provide an opportunity for our funding partners and stakeholders (Auckland Council, Auckland Emergency Management, the New Zealand Earthquake Commission, and the Tūpuna Maunga o Tāmaki Makaurau Authority) to provide feedback and suggest future research directions according to their priorities.

Throughout the research programme, efforts by DEVORA to build relationships and maintain reciprocal, open lines of communication between scientists and stakeholders have created a strong, cohesive, engaged community for our partners to draw upon as we prepare for the next AVF eruption. This successful model has been emulated by other hazard research programmes across New Zealand and internationally.
Vision for next 5 years

1. Determining volcanic risk

To date, the focus has been on evaluating the hazard and impacts of possible future eruptions in Auckland. However, as we collect more and more data we are reaching the stage where we can begin to move towards assessing probabilistic risk in Auckland. Within the RiskScape tool, Auckland is split into a grid and the substrate noted at each grid location (e.g. Fig. 14). Each DEVORA scenario will be able to be run in any grid location (providing it has the correct substrate for that scenario) to examine impacts and effects of various hazards on Auckland’s infrastructure. The likelihood of these scenarios occurring in these locations is the next step towards developing a probabilistic volcanic risk model (which includes spatial diversity) for Auckland.

![RiskScape Diagram]

Figure 14. DEVORA researchers have worked to improve the RiskScape tool for a variety of volcanic hazards and their impacts. The tool predicts quantifiable impacts (damage states, repair costs, risk to human life) for a number of hazards, the results of which then can be compared. This example examines the impact of a certain thickness of ash fall on a weatherboard building with a sheet metal roof. Other volcanic hazards such as lava flows, base surges, vent/edifice building, and ballistics are being added to the tool.

1. Geophysical investigations of the crust

DEVORA affiliated researchers have to date “discovered” four new volcanic centres using borehole data and high-resolution spatial mapping. This suggests that we may not know all of the AVF eruptive centers (e.g. underwater vents, small eruptive centers, centres buried by more recent eruptions) and future work is needed in this space.
3. **Research to support cost-benefit analysis of novel and trusted monitoring techniques**

Research which leads to better surveillance for better evacuation and emergency response decision making could save lives and is a priority for DEVORA. We have a suite of possible novel monitoring techniques derived through an informal expert elicitation process. The next step is to evaluate the benefits of the most promising ranked opportunities, and to make evidence-based recommendations to Auckland Council and GeoNet for further cost-benefit analysis. This will inform further investments in monitoring, and has the potential to make Auckland a safer community through earlier warning and/or more certainty in vent location and timing.

4. **Interdependence modelling for Auckland lifeline resilience**

DEVORA researchers plan to collaborate with The Resilience to Nature’s Challenges phase 2 (National Science Challenge) on interdependence modelling for Auckland lifeline resilience. The scenarios that we have developed in DEVORA provide an excellent foundation for probabilistic approaches.

5. **Loss-of-service/functionality modelling of waste and stormwater for a syn- and post-eruption environment in Auckland**

The potential for damage and disruption from ash from future eruption, whether direct or indirect (e.g. ash into drains) will cause an epic public health and environmental disaster. We plan to collaborate with storm/wastewater engineers to investigate the scale of the likely impacts and most appropriate mitigation methods.

6. **Fire following eruption**

Fire following eruption is a new research area that is emerging for DEVORA. During and immediately after volcanic eruptions, fires can be ignited from lava flows and hot ash, and may in fact end up being one of the most challenging hazards we face in the event of a future volcanic eruption in an urban area such as Auckland. We need more research into the propensity of this hazard, and possible mitigation methods.

7. **Multi-hazard/multi-risk assessment**

It is rare that a hazardous event occurs in isolation yet we often assess and model hazards and their impacts individually. Looking forward we plan to place more emphasis on multi-hazard approaches. This applies to the way we view volcanic eruptions, for example, we wish to assess multi-hazard habitability of buildings and urban areas. This demonstrates our holistic approach of thinking beyond the evacuation to more of “how will we live and thrive with and after a future eruption”. It also applies to how we view volcanic eruptions in the context of other hazards, for example, in collaboration with our RNC collaborators we will investigate the value of multi-hazard risk mapping for Auckland. Such multi-risk approaches will include lifeline, economic, environmental, social/welfare and recovery aspects, and will include exploring the range of possible scenarios and associated hazards at all credible locations across a grid of possible locations across the entire city of Auckland.
Summary - Benefit Statement

- The funding and partnership with DEVORA is unique in AC, in that it is currently the only comprehensive programme of work that AC supports to research, understand, plan for and mitigate the risk of one of Auckland’s potentially most catastrophic natural hazards.

- The DEVORA programme has garnered international accolades, and has helped boost Auckland’s reputation as a global leader in emergency management planning. An investment in DEVORA is good value for money. Funding into the programme contributes to an overall spend of $600,000, thus a $100,000 investment leads to $600,000 worth of outcomes. $200,000 is directly co-funded by EQC and an approximate further $300,000 in value is contributed by The University of Auckland and GNS Science through in-kind funding of time and research.

- DEVORA represents a clear strategy to address key threats facing Auckland. Not only does DEVORA address risk from a local AVF eruption, it also addresses threats from distal volcanoes, particularly in NZ, which are more likely to erupt than the AVF. One DEVORA finding indicates Taranaki is most frequent ash fall contributor to AKL; Taranaki CDEM places the Annual Exceedance Probability of a Taranaki eruption at 3%.

- Knowledge of the inner workings of the AVF, the likely hazards, and the impacts of an eruption have been greatly improved by DEVORA researchers. However, critical uncertainties and areas for further study remain. Benefits of investment in future DEVORA research could include:
  - improved hazard models.
  - improved evacuation estimates.
  - clearer warning times.
  - improved understanding of likely eruption hazards.
  - reduced life risk.
  - avoidance of over-conservative evacuations (too early or too large).
  - improved understanding of potential damage to infrastructure, resulting in useful recovery planning.
  - improvements to resilience through design.
  - detailed knowledge of the crustal structure.
  - increased knowledge of Auckland’s seismic hazards and our understanding of the general stress field of the Auckland region, which was identified as one of the top hazards to the Auckland region in the Auckland Civil Defence and Emergency Management Group Plan.
CITY OF VOLCANOES
THE AUCKLAND VOLCANIC FIELD NGĀ TAPUWAÉ Ō MATAAHO

An Introduction to Auckland’s volcanoes

The Auckland Volcanic Field (AVF), or Ngā Tapuwaē Ō Mataaho, is the name given to the volcanic area located in Auckland / Tāmaki Makaurau, New Zealand. The AVF is different to the volcanic systems that construct big volcanic cones in the central North island of New Zealand, such as Mt Ruapehu or Taranaki. The AVF tends to erupt in a new location each time, instead of experiencing repeated eruptions in one location. The AVF eruptions also tend to be much smaller in scale. This type of activity has resulted in many small hills and pits across the Auckland landscape, rather than one big cone. This fact sheet shares some interesting facts about Auckland’s many volcanoes.

Pupuke
Auckland’s Oldest Volcano

Lake Pupuke is up to 200,000 years old. The lake formed in a volcanic explosion crater that filled with water over time. Such explosion craters, called maars, form when hot rising magma comes into contact with water, causing the water to quickly heat into steam and create an explosion that breaks and ejects the surrounding rock to form a crater.

Rangitoto
Auckland’s Youngest Volcano

Rangitoto’s full name is Ngā Rangitoawhia a Tamatekapua, after a Māori captain who was wounded there. It experienced at least two eruptions about 600 years ago. Lava flows made up the volcano’s broad slopes, and a scoria cone made of loose rock forms the cone shape at the top. Lava tubes can be found throughout Rangitoto. These tunnels were formed when the outer surface of the lava cooled and hardened before the inside, which continued to flow.

AVF: from magma to lava

- When magma erupts at the surface, it is called lava. Lava may erupt fluidly, or it may be explosively erupted into fragments.
- Once magma reaches the hard crust beneath Auckland, it will start to break the rock, causing earthquakes.
- The small batches of magma within the Earth’s crust that rise up towards the Earth’s surface form a layer of hard, solid rock near the Earth’s surface. Magma refers to molten or partially molten rock beneath the surface. The AVF does not have any large magma chambers. Instead, its eruptions come from small magma batches that rise up from 50 km deep down in the Earth’s mantle.

Maungakiekie
One Tree Hill

Maungakiekie is an example of a scoria cone. The cone is made up of basaltic scoria – a dark, iron-rich, fragmented volcanic rock with vesicles (holes). The vesicles were once filled with volcanic gases, and indicate that the eruption was moderately explosive.

DID YOU KNOW?
Many of the volcanoes in the Maungatautari Volcanic Field were Maori pa sites, making up the biggest network of defensible settlements in Polynesia. In 2014, 14 of the maunga were returned to the Trust Board of Tāmaki Maunga Authority.

DEVOA 2017 | devoa.org.nz

DEVOA FACT SHEET 01
Determining Volcanic Risk in Auckland (DEVOA) Project
The Auckland region has a long history of being affected by volcanic eruptions. The region has experienced at least 53 eruptions from the Auckland Volcanic Field (AVF) in the past 200,000 years, and it has been covered by ash from central North Island volcanoes at least 300 times during that period. To determine exactly how often the Auckland region has been affected by eruptions, scientists study ash layers that have been preserved in lake beds. They now think that ash has fallen on Auckland at least once every 600 years!

What is volcanic ash?

When volcanoes erupt, they eject small fragments of broken rock and lava into the air. This material is called tephra. Tephra less than 1 mm in size is called ash. Ash is so small and light that it is easily picked up and carried by the wind. Ash can travel hundreds of kilometres before settling out of the ash cloud and falling to the ground.

Why are ash layers important?

Scientists study the pattern of ash layers in lake sediment cores to figure out how often volcanic eruptions affect a certain area. They discovered that sometimes ash layers from Auckland volcanoes were close together in the cores, meaning there were lots of eruptions within a short time, and sometimes there were large gaps between ash layers, meaning that there was a long time gap between eruptions. This irregularity makes it impossible to predict when the AVF will erupt again.

Cryptotaupho = Secret + Ash

Some eruptions are only preserved as scattered grains of ash in tiny layers. Known as cryptotaupho, these layers get their name from crypta, the Greek word for ‘secret’, and are made of glass shards so small that scientists have to use a special microscope to even see them. Cryptotaupho layers are sometimes the only evidence that an eruption ever happened.

The last time ash fell on Auckland was when Ruapehu erupted in 2007. Ash fell as far away as Christchurch and cost the city millions of dollars. For more information on the impact of ash fall visit:
https://volcanoes.usgs.gov/volcanic_ash

How can we tell where ash layers come from?

COLOUR

A white layer = Ash from a large, more distant volcano (e.g. Taupo).
A black layer = Ash from a smaller, local Auckland volcano (e.g. Mt. Wellington).

LOCATION IN THE CORE

Some large-scale volcanic eruptions are so well studied that their ash is immediately recognisable in the core. When scientists find these ash layers, they use their ages to help figure out the age of other ash layers in the core. Ash layers below a well-studied eruption are older, while ash layers above are younger.

CHEMISTRY

Volcanoes often have a unique chemical fingerprint. If the chemistry of an ash layer matches that of a previously studied eruption from a known volcano, scientists can say which volcano erupted the ash.

THICKNESS

The thickness of an ash layer depends on the distance from the volcano and the size of the eruption. A thick ash layer means that the eruption was either very big or very close by, while a thin ash layer means the eruption was either small or far away.

WHAT DO YOU SEE?

Using the information above, what do you see in this image?

Is this layer from a previous eruption or is it the ash fall from the eruption that made this layer?

Where are the white layers from—local or distant?

The chemistry of this thin black layer matches those from Mt. Wellington. We know this ash erupted ~10,000 years ago because the white ash layer beneath it came from the eruption 60,000 years ago. The black ash fall is older, and the ash fall is older than the age of this and other Auckland eruptions.
VOLCANIC ASHFAIL
ADVICE FOR WATER SUPPLY MANAGERS

Ash Impacts On Drinking Water Treatment
- Ash suspended in water increases turbidity in raw water sources.
- Create high water demand during the cleaning phase.
- Cause problems in filtration systems water treatment plants.

Effects on Raw Water Sources
In general, the impact of ashfall on drinking water sources is minimal with little evidence of chemical composition.

Effects of ashfall on raw water quality
Ash suspended in water increases turbidity in raw water sources. Villagers at risk may be exposed to fecal matter and other contaminants. In addition, the water becomes cloudy and difficult to use for drinking.

Water Demand
Water demand is typically lower after an ashfall event, but managers should be prepared to meet increased demand.

Recommended Actions
WHERE TO FIND WARNING INFORMATION
- Review weather forecasts in the event of a volcanic eruption.

HINT TO PREPARE
- Make water treatment plants have adequate water treatment facilities.
- Ensure that all pumps are functioning properly.
- Check all filters and membranes for damage or disorientation.

Effects on Treatment Plants
VOLCANIC ASHFAIL CAN CAUSE A RANGE OF OPERATIONAL PROBLEMS FOR WATER TREATMENT PLANTS:
- Ash suspended in raw water increases turbidity at the water treatment plants.
- Pumps used for distributing water may become inoperable due to clogging or electrical failure.
- Ultraviolet (UV) or chlorine treatment may be ineffective due to ash contamination.
- Filters may be clogged, leading to inefficient water treatment.

Adapted from a presentation by Dr. K. Doe, University of XYZ, 2023.

Further Resources
- http://www.enviro.govt.nz (volcanic ash monitoring information)

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