

An update from the lab...

Volcanic Ash Testing Lab (VAT Lab)

National Lifelines Forum – 23 September 2010

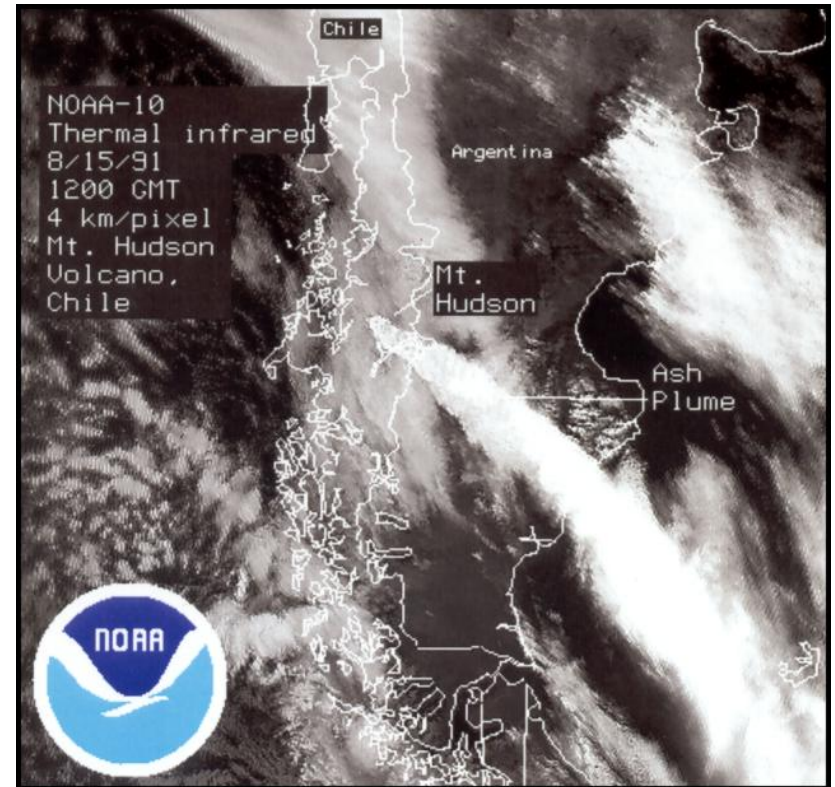
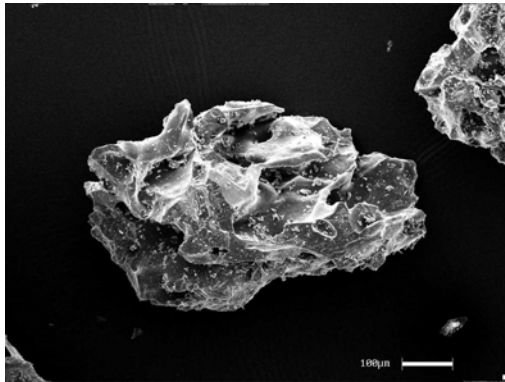
Tom Wilson, John Wardman, Carol Steward, David Johnston, Pat Bodger, et al.

University of Canterbury, GNS Science, Massey University, etc



What is volcanic ash?

- Abrasive
- Chemically corrosive
- Electrically conductive
- Variable grain size ($<2\mu\text{m}$)



- Eruption size, wind direction & speed affects distribution
- Most impacts tend to be disruptive rather than destructive
- Ashfall most frequently affects the most people

Changing Risk Landscape

- Development is increasing risk in known hazards zone
- Potentially adding substantial risk where little or none existed before (true for all natural hazards)
- Smaller magnitude events at volcanoes will cause **more damage and disruption**

TABLE 5. SOCIETAL CHANGES OVER THE PAST 50 YEARS (1945–1995)

Measure	1945	1995
New Zealand population	1 702 330*	3 579 900 [§] (1995)
Hawkes Bay	49 796*	116 340 [#] (1991)
Taupo District	4 248*	30 723 [#] (1991)
Ruapehu District	15 320*	18 105 [#] (1991)
Cars (number)	198 629 [†]	1 647 134 [§] (1995)
Cars/head of population	0.12	0.46 (1995)
Speed limit (open road)	64 km/h (40 mph)	100 km/h
Domestic air travel — passenger no.	60 968 [†]	4 502 000 ^{**} (1993)
Domestic air flights/head of pop.	0.036	1.3 1993
Ski fields on Ruapehu	1	3
Number of ski lifts	0	36 (1995)
Number of skiers days	N/A	450 000 ^{††} (1994)

*1945 census.

†1945 Yearbook.

§1996 Yearbook.

#1991 census.

**Ministry of Transport.

††Ruapehu District Council.



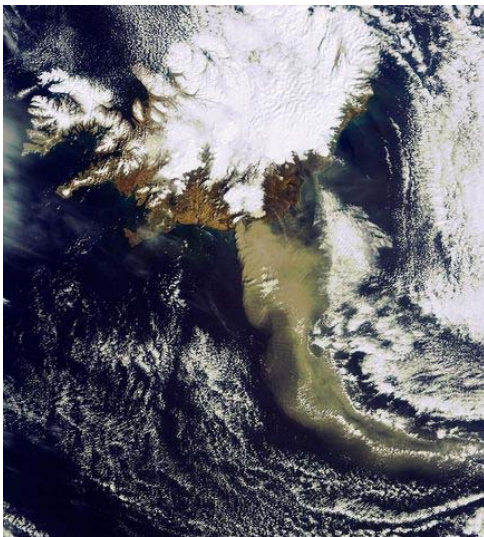
Research Context – Volcanic Impact Research

- Over the past 10-15 years the New Zealand research group (and collaborators) have aimed to undertake a sustained and systematic approach to volcanic impact assessment
 - critical infrastructure: **electricity, water supplies, wastewater, land and air transport, telecommunications**
 - ash cleanup and disposal
 - primary industries, including agriculture
 - social impacts
 - emergency management
- Reconnaissance trips to impacted areas, e.g. Yakima, Spurr, Kagoshima x2, Catania, Ecuador, Merapi, Pinatubo, Hudson, Iceland agriculture, Heimaey, Chaiten, Redoubt
- Followed by laboratory testing of critical infrastructure components...VAT Lab



Eruption of Eyjafjallajokull, Iceland

- >300 million euro in direct economic loss (airlines), potentially billions of euro lost in service disruption, and a large social impact
- Scientists have been demanding ash concentrations thresholds be provided by the airline industry for **decades**
- Under the present CAA limits and according to high-resolution models the impact of the same event today would be considerably less
- **Highlights the extreme lack of knowledge around ashfall impacts to critical infrastructure and communities**



VAT LAB

VOLCANIC ASH TESTING LABORATORY



VAT LAB is a consortium of research organisations investigating the impact of volcanic ash fall on infrastructure.

Volcanic Impact Assessment
 Infrastructure Vulnerability Assessment
 Critical Component Testing

Volcanic Ash can be:

very fine grained
 highly abrasive
 corrosive
 conductive



Volcanic Impact Assessments:

Alaska (1996), Argentina (2008; 2009), Chile (2008; 2009), Ecuador (2004; 2005), Iceland (2008), Indonesia (2008), Japan (2001; 2007), New Zealand (1995-1996), Philippines (2001; 2007), Vanuatu (2000-2009)

Completed research projects of critical components:

Vulnerability of computers to volcanic ash ingestion
 Vulnerability of air conditioning units to ashfall
 Vulnerability of water pumps to volcanic ash ingestion

Current research projects:

Vulnerability of high-voltage electrical distribution systems
 Infrastructure performance following the 2008 Chaiten eruption, Chile & Argentina
 Vulnerability of water supply systems in Vanuatu
 Volcanic mitigation measures in Alaska

David Johnston
 david.johnston@gns.cri.nz

<http://www.gns.cri.nz>
<http://disasters.massey.ac.nz>

Thomas Wilson
 thomas.wilson@canterbury.ac.nz

<http://volcanic.massey.ac.nz>
<http://www.nhrc.canterbury.ac.nz>

what we do

volcanic ash

activities

contact

Consortium of research organisations investigating the impact of volcanic ashfall to infrastructure

Link between Geology, Engineering and Societal themes

Active collaboration with:

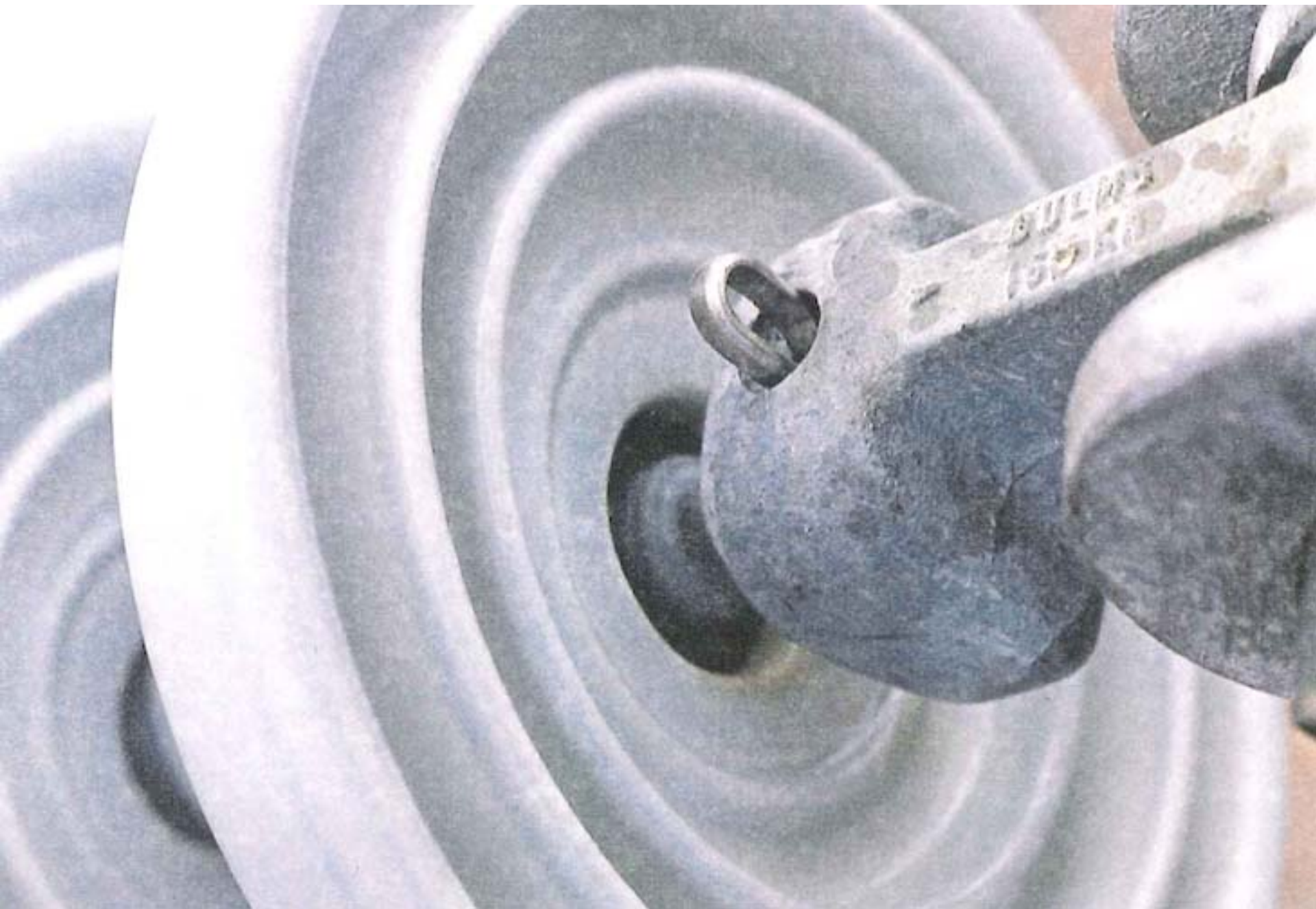
- University College London,
- University of Cambridge,
- Bonneville Power Administration,
- USGS



Ruapehu 1995

- Lines close to volcano contaminated by falls of volcanic ash and mud
 - Bunnythorpe – Tokaanu A/716
 - Towers 290-350 (320-330 critically affected)
 - Bunnythorpe – Tokaanu B/718
 - Towers 292-350 (320-330 critically affected)
 - Bunnythorpe – Wairakei A/721
 - Towers 310-370 (340-350 critically affected)
- Flashover and voltage fluctuation
- Exposed surfaces coated in 3mm of ash





Post Eruption

27th September, 1995

- 4 Crews of 4 men dispatched
- 18 towers

Cleaning methods:

- Water Blasting (1500 psi)
- Fire Hosing
- Dry wiping (mutton cloth)
- Knapsack sprayer & cloth

Estimated cleaning costs:

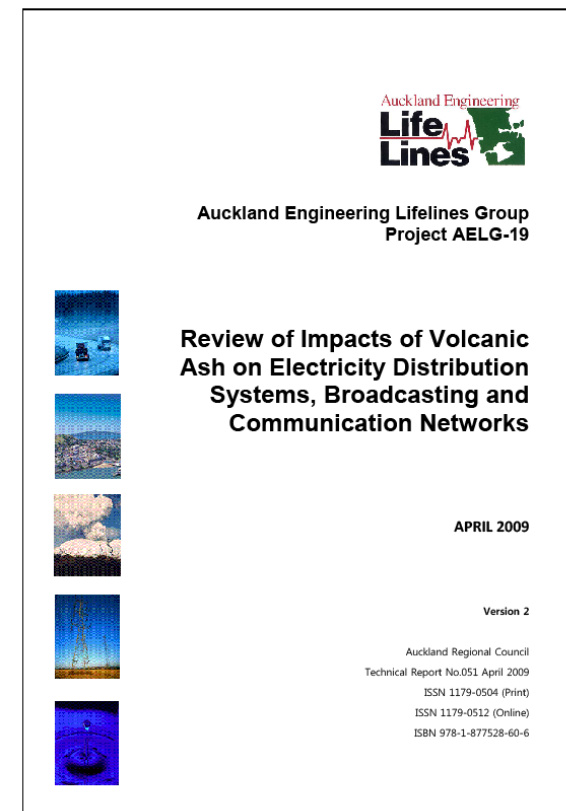
- De-energised cleaning of insulators (1 day, 1 crew): \$2,040.2,
- Cleaning of structures (1 week, 1 crew): \$10,470.6,
- Live-line Cleaning with hotstick (1 day, 1 crew): \$3,125.2,



AELG – 19

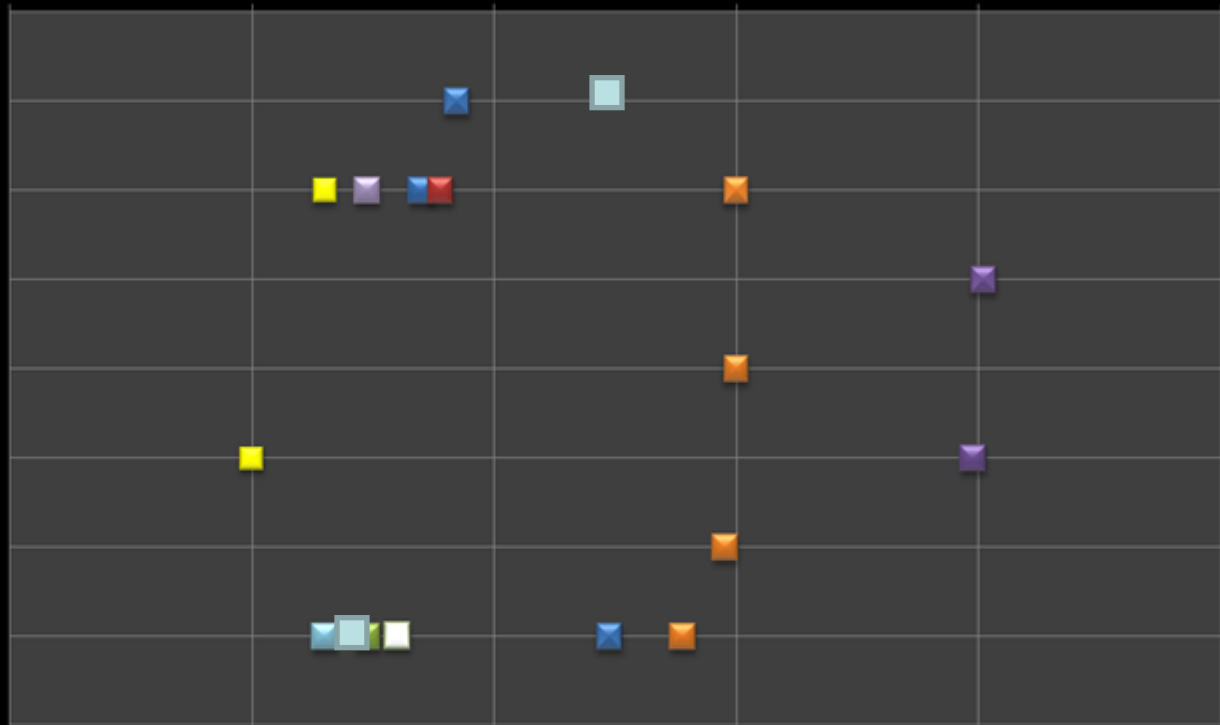
Electricity, telecommunications & broadcasting

1. To summarise the information and research undertaken (nationally and internationally) on the impacts of volcanic ash on **electricity distribution systems, broadcasting and communication networks**.
2. To identify **vulnerable components** of electricity, broadcasting, radio transmission and communications networks to ash.
3. To identify **mitigation measures** to reduce vulnerability prior to a volcanic event, and measures to reduce damage during and post event.



Ashfall Thickness (mm)

0.1 1 10 100 1000 10000



- St Helens - 1980
- Rebut - 1989
- Mt Spurr - 1992
- Rabaul - 1994
- Ruapehu - 1995/96
- Hudson - 1991
- Sakurajimia - 1980-90's
- Reventador - 2001
- Merapi - 2006

FLASHOVER – high voltage network

FLASHOVER – low voltage network

OBJECTS COLLAPSING ON LINES

TRANSFORMER DAMAGE

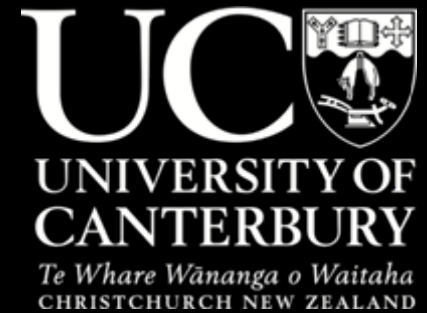
CONTROLLED OUTAGE

LINE COLLAPSE FROM ASH BUILD-UP

RESILIENCY TO ASH

Quantifying the Vulnerability of High Voltage Transmission Systems to Volcanic Ashfall Hazards

Wardman, J.B., Wilson, T.M., Bodger, P.S.,
Cole, J.W., Johnston, D.J.



Electrical Resistance Testing

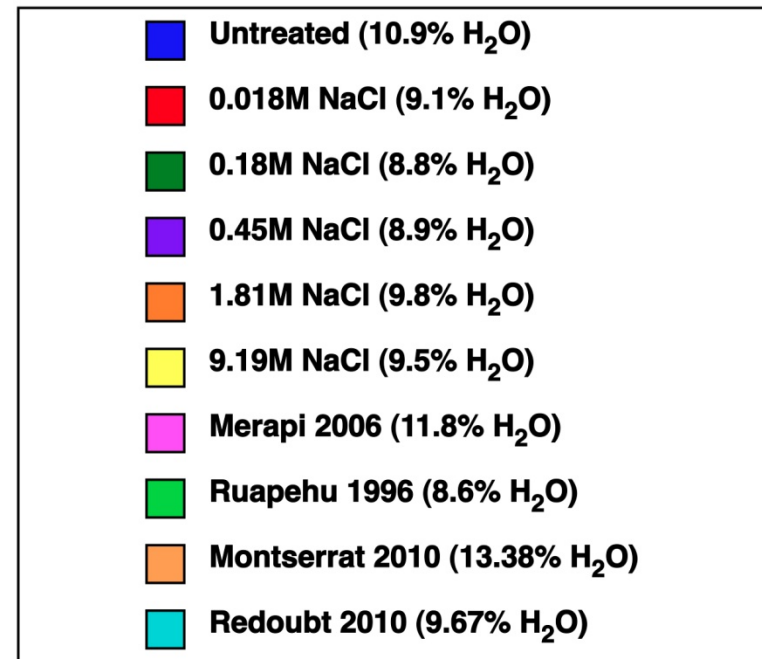
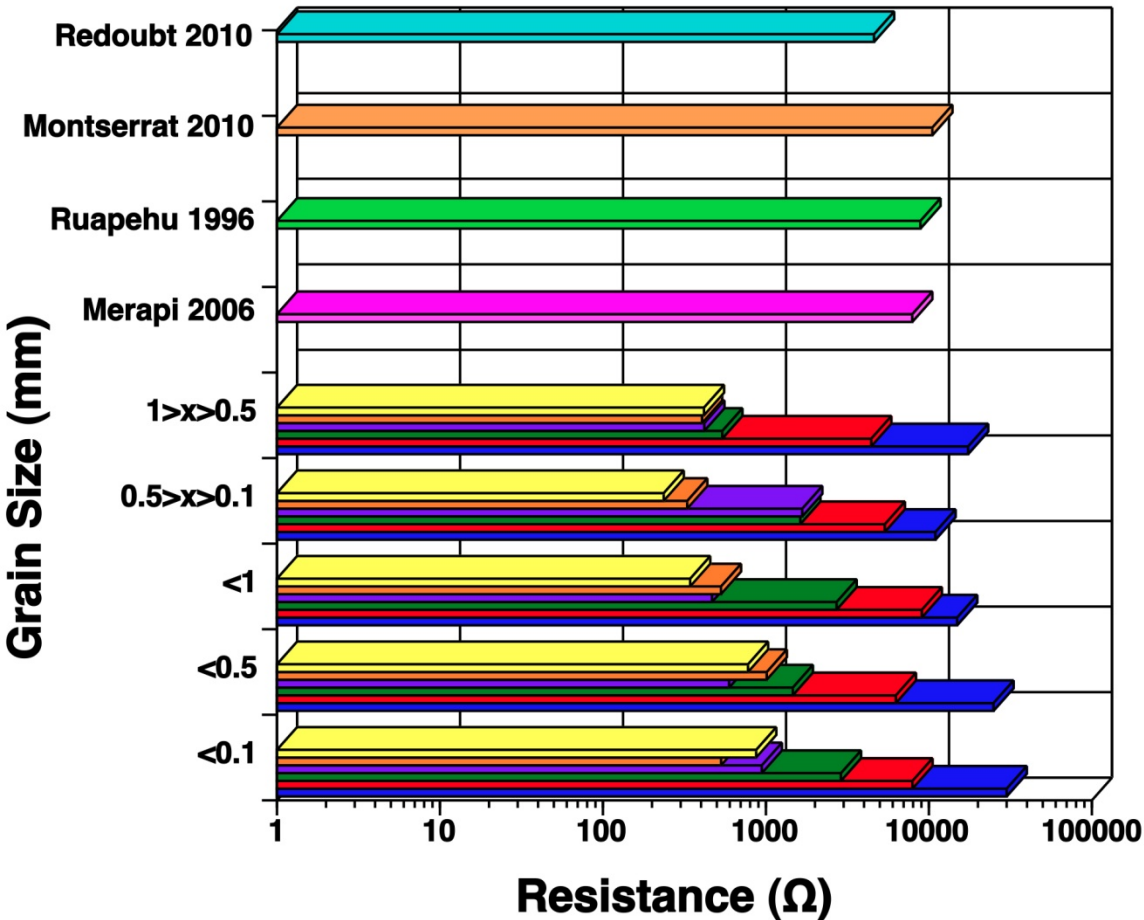
- Opportunity to implement a new practice
 - International interest
- Measure resistance of various ash types in 'electrode dock'
- Cleaning when ESDD $\geq 0.03\text{mg/cm}^2$
- Nellis & Hendrix 1981: Ash 3-6mm thick=ESDD **0.3-0.6mg/cm²**
- Investigate controlling variables
- Compare & Identify suitable proxy



ESDD (mg/cm ²)	Site Severity
0 – 0.03	Very Light
0.03 – 0.06	Light
0.06 – 0.1	Moderate
>0.1	Heavy

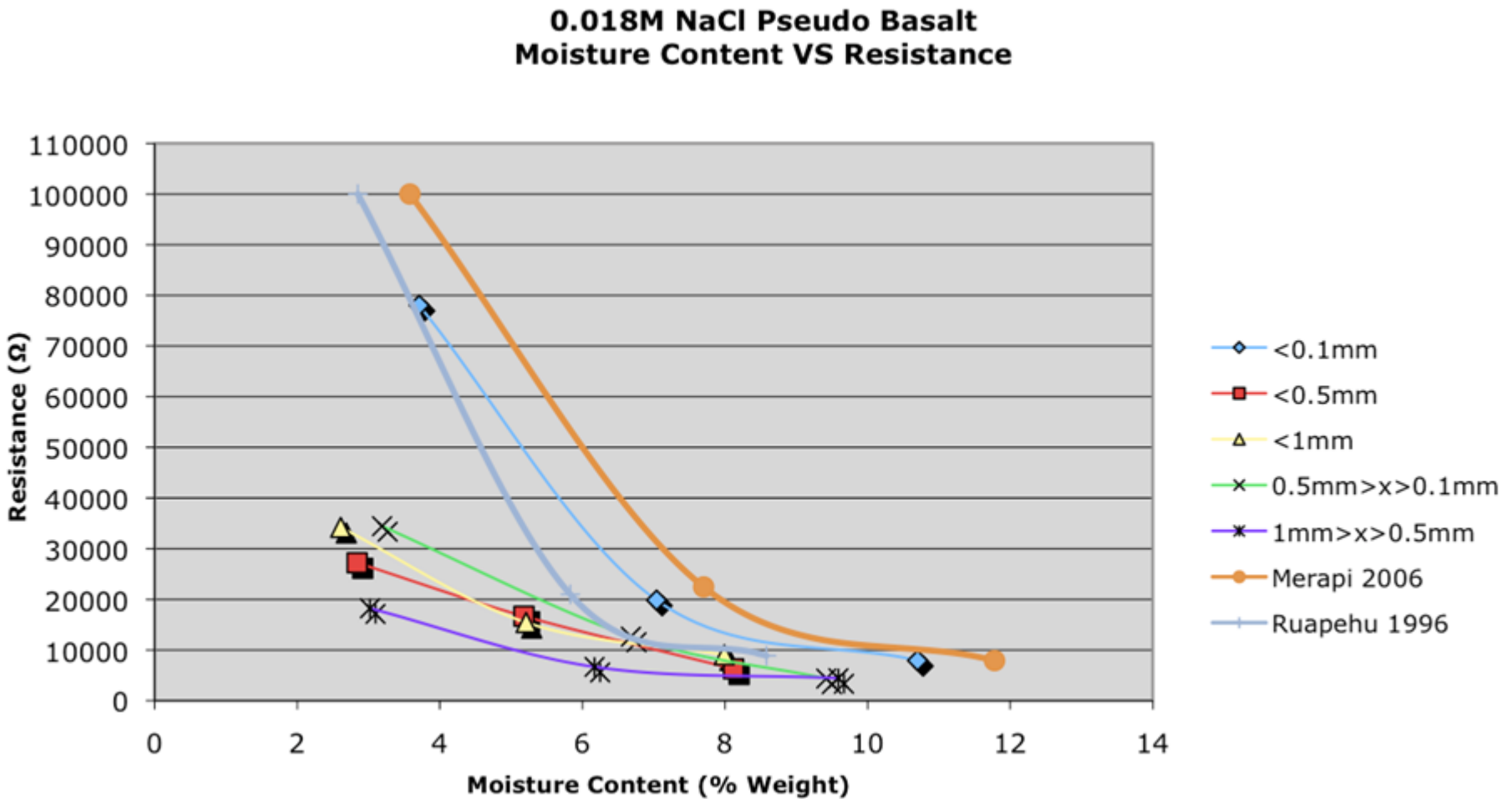
Characterizing the resistivity of volcanic ash

NaCl Pseudo Basalt Grain Size VS Resistance

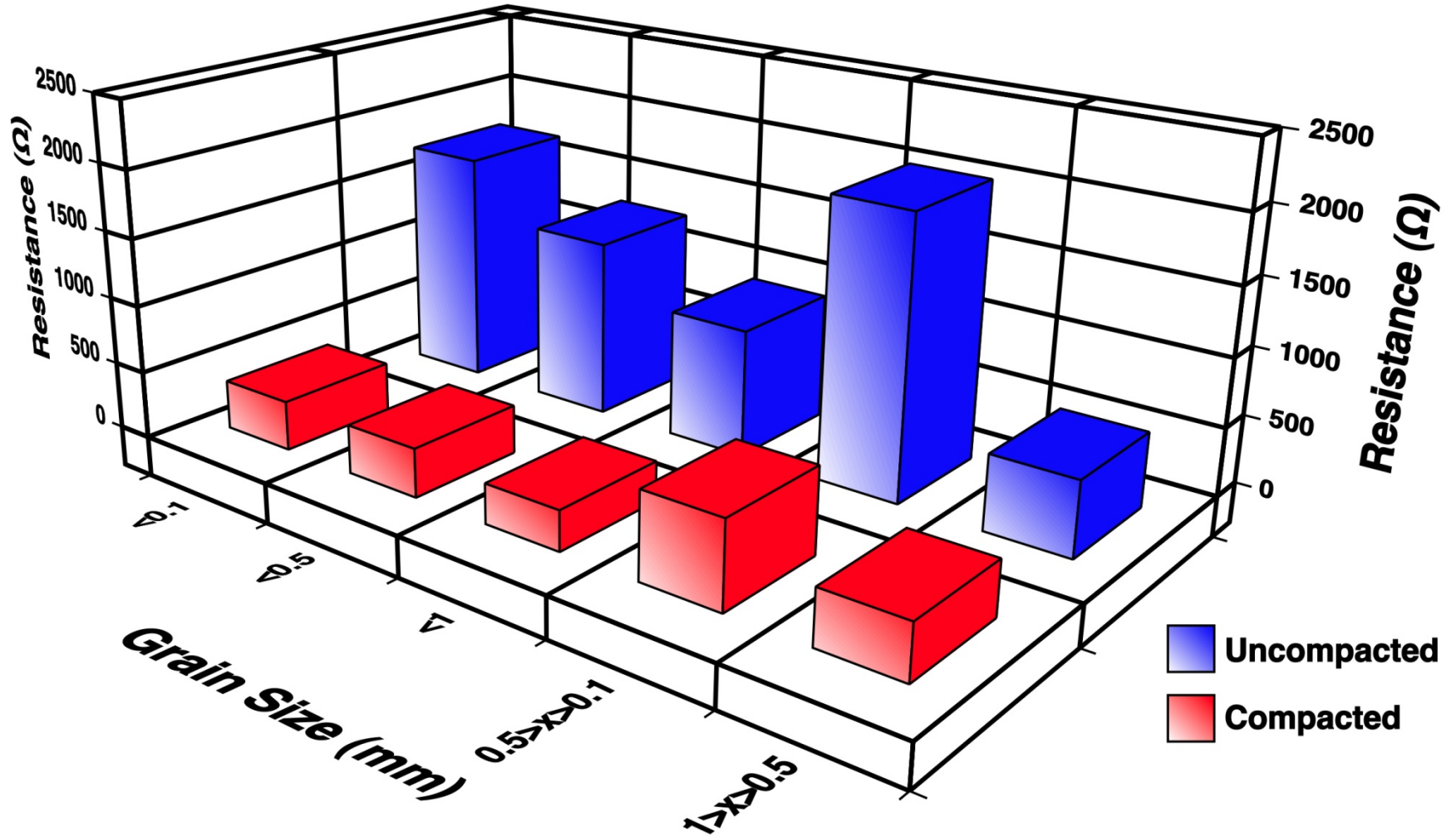


Water Content of the ash

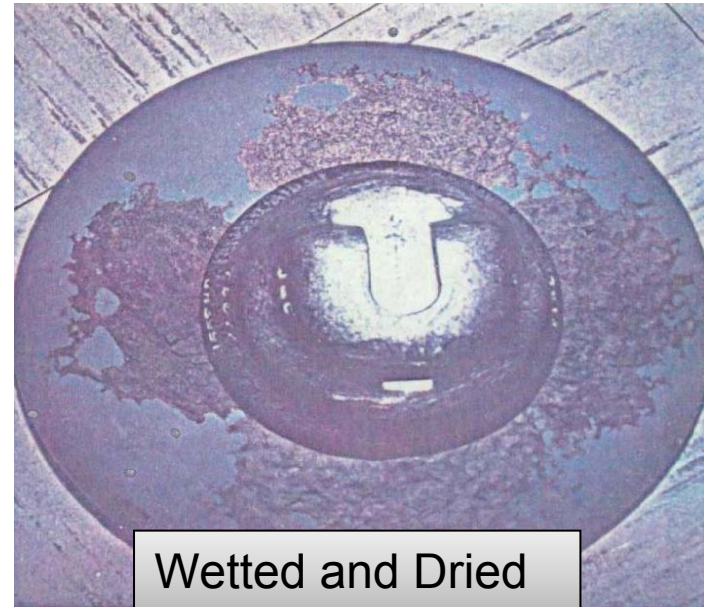
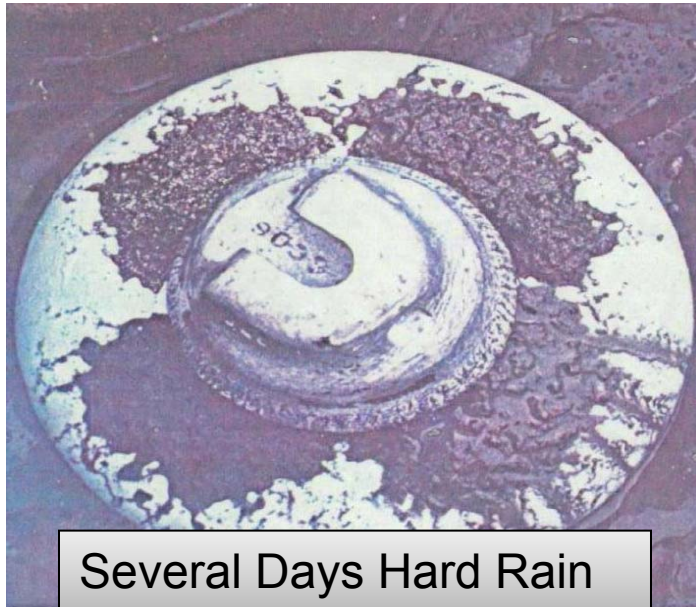
- \uparrow Water Content = \downarrow Resistance



Compaction Test 1.81M NaCl Pseudo Basalt



Adherence Properties



Contamination Testing

- Power-frequency testing of high voltage insulators contaminated with volcanic ash
 - 350 kW power capability, 50 Hz
- Test insulators of varying ratings, design and composition
 - Porcelain, glass, composite polymer
- Control and quantify major variables leading to flashover
 - i.e. moisture type/rate, ash volume, grain size, etc.
- Leakage current and geotechnical analysis of adherence properties



Clean String



Contaminated with 3mm ash

movie

Insulator Design

A central aim is to:

- Inform design criteria for volcano proximal or heavily polluted areas
- Self cleaning options?
 - Corona wind
 - TiO_2 (titanium dioxide) film (Yuzhen *et al.*, 2009)
 - Effectiveness of RTV greases?



Grant Wilson – MSc @ UC



Early results

- All laptops kept working and are still working – tested on a 1 month cycle...
- Laptop 2 showed the most effects
 - Copper of heat sink and copper tape were discoloured
 - Some rust on internal stainless steel
 - Screen and keyboard were covered in H_2SO_4 residue
- Other laptops showed little effect
- USB cable plugs corroded
- Ash testing is next....



Ash fall impacts to roofing

Common misperception that ashfall will cause roof collapse due to structural collapse

- Reality is that only 0.01% of the exposed building stock will fail in a major ashfall
- Falls from roofs is one of the largest causes of injury and death following an ashfall in modern situations

Futaleufu, Chile received 200mm of ashfall followed by snowfall 10 days later.

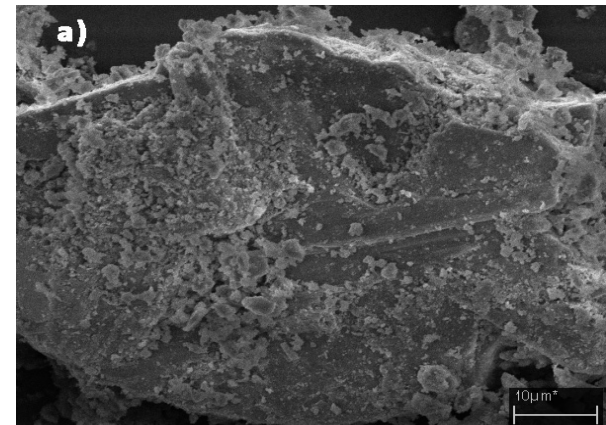
- No structural collapse occurred
- >25% of the building stock exhibited heavy rust damage >20% suffered gutter collapse or damage.



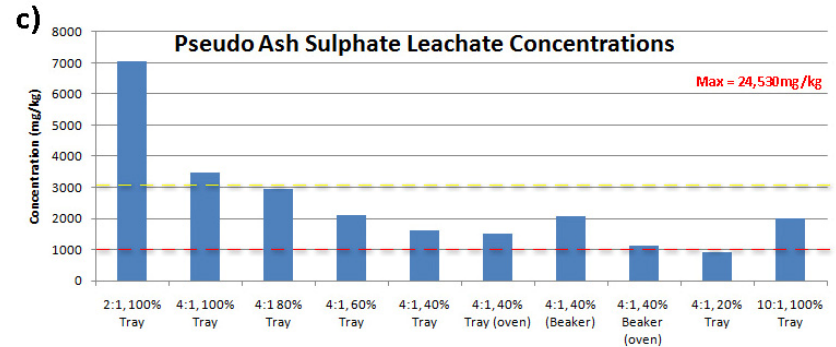
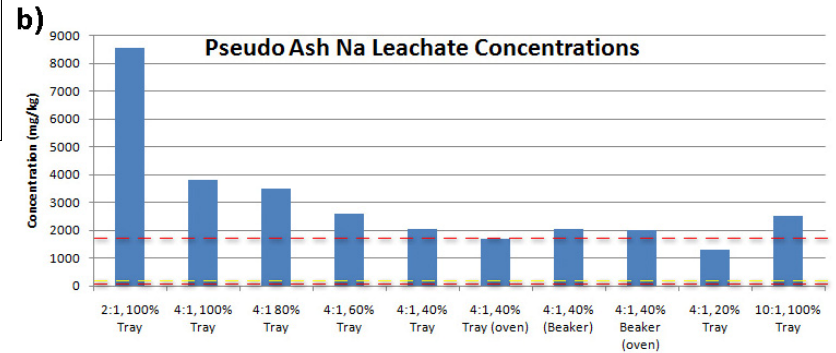
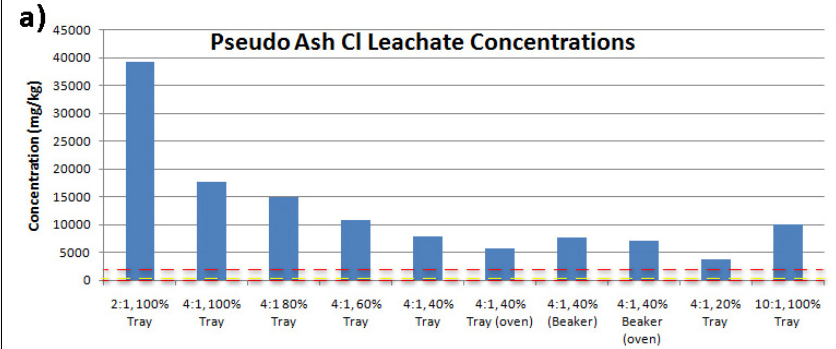
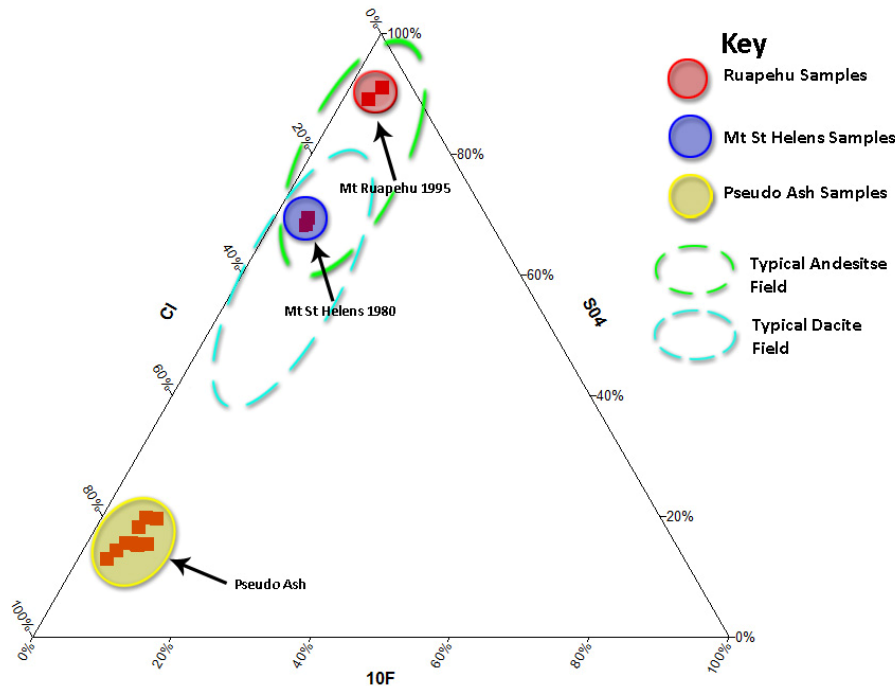
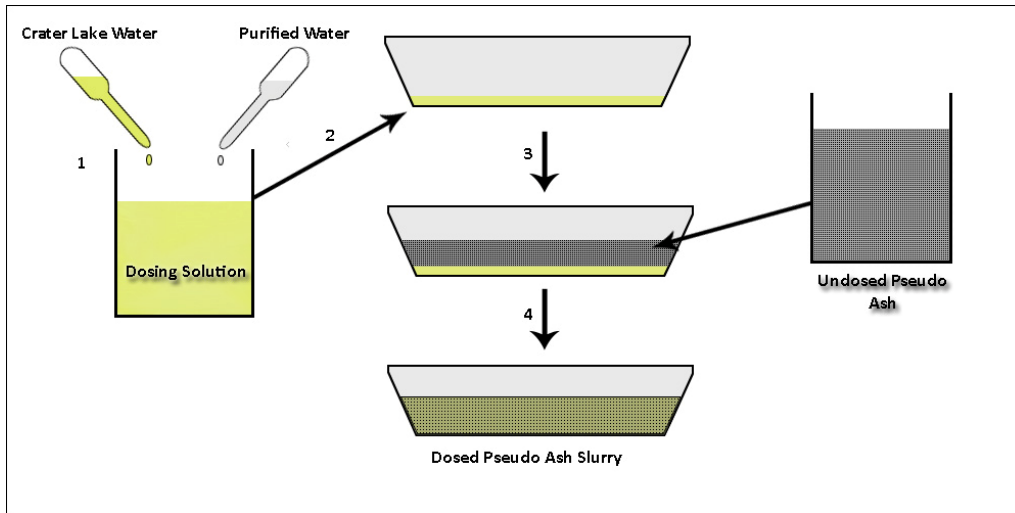
Ash fall impacts to roofing

1. The vulnerability of standard New Zealand metallic roofing and gutter materials to corrosion following volcanic ash exposure over time
2. Deterioration rate of metallic roofing and gutter materials roof
3. Performance of standard New Zealand gutters under ash loading

Sam Broom, Dean Podolsky, Jim Cole, Kerry Swanson, BRANZ, et al.



Wastewater analysis – effectiveness of flocculants



Ash Impacts Posters

VOLCANIC ERUPTION ADVICE FOR ELECTRICITY NETWORK MANAGERS

ASH IMPACTS ON ELECTRICITY DISTRIBUTION

Volcanic ash is hard, highly abrasive, mildly corrosive and conductive.

Volcanic ashfalls can cause disruption to electricity supplies in the following ways:

- Ashfall buildup on insulators can lead to flashover (the uncontrolled disruptive discharge over or around the insulator), causing disruption to distribution networks.
- Line breakages and damage to towers and poles due to ash loading, both directly onto the structures and by causing treated onto lines, particularly in heavy, the ashfall events. Snow and ice accumulation on lines and vegetation will exacerbate the risk.
- Breakdown of substation and other equipment such as air conditioning/cooling systems due to ash penetration which can block air intakes and cause corrosion.
- Controlled outages during clearing.

If these, the main hazard to insulator flashover. Volcanic ashfall may also increase electricity risks (by increasing touch potentials) to workers in substations.



INSULATOR FLASHOVER

Factors contributing to risk of flashover include:

- Light salt weather conditions close to the surface of light rain wets the ash and leads to a conductive layer forming on the surface which induces leakage current and leads to string and flashover.
- However rain will wash off contaminants.
- Ash granules fine ash adheres to insulators (more strongly).
- Presence of other contaminants e.g. salt, soil, agricultural sprays, smoke.
- Delayed time since last maintenance.
- Insulator design and construction (ability to shed ash and resist acidic corrosion).



RISK OF DAMAGE TO TOWERS, POLES AND LINES

Towers and poles	Ash thickness <100mm		Ash thickness >100mm	
	Low ash	High ash	Low ash	High ash
Low	Low	Low	Low	Medium
High	Low	High	Low	High
Lines	Low	Low	Low	Medium
High	Low	High	Low	High

ELECTRICITY RISK

Readiness of ground grid to accept the voltage following ashfall, reducing step potential and contact voltages to safe levels.

RECOMMENDED ACTIONS

General notes on cleanup of ash:

- Plan to avoid routine maintenance in areas affected, especially in coastal areas.
- During an ashfall, monitor buildup of ash on insulators. If conditions are not suitable, schedule maintenance to be performed.
- Immediately after an ashfall, discontinue to substations to test, wipe and clean all wet electrical equipment, and clean work on poles.
- Use of increased electricity load to assist users the ground, because maintenance to electrical equipment during ashfall.



The following resources provide further information on volcanic hazards:
<http://www.nzta.govt.nz>
<http://www.civildefence.govt.nz>
<http://www.fire.govt.nz>
 Drafted by Tom Wilson, Carol Stewart & David Johnson, 20 August 2009

VOLCANIC ERUPTION ADVICE FOR WATER SUPPLY MANAGERS

IMPACTS ON WATER SUPPLIES

Volcanic ash is highly abrasive, mildly corrosive, conductive.

Freshly-fallen volcanic ash may result in: short-term physical and chemical changes in water quality; increased wear on water delivery and treatment systems; disruption of electrical power supplies; and high demand for water during clean-up.



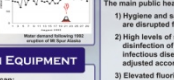
WATER DEMAND

Water use	Ash thickness <100mm		Ash thickness >100mm	
	Low ash	High ash	Low ash	High ash
Low	Low	Low	Low	Medium
High	Low	High	Low	High
Lines	Low	Low	Low	Medium
High	Low	High	Low	High

WATER DEMAND

High demand for water typically occurs after an ashfall and can lead to temporary water shortages.

This may compromise key services, such as fire-fighting capacity.



EFFECTS ON EQUIPMENT

Suspended ash in water can:

- Block intake structures.
- Cause abrasional damage and increased wear of equipment.
- Block filters and clarifiers and generate increased waste.
- Increase pH which can in turn increase turbidimetry.

Airborne ash particles can:

- Clog air filtration systems, causing overheating and engine/motor failure.
- Block and restrict moving parts of equipment and motors.
- Cause icing and flash-over due to electrical equipment.

RECOMMENDED ACTIONS

Anticipate increased water demand for clean-up operations:

- conservative water for human consumption
- where possible use alternative, non-potable sources of water for clean-up and fire-fighting, and encourage clean-up with brooms and shovels rather than hoses.

Monitor potentially hazardous components of water (pH, turbidity, fluoride)

Review stocks of essential items such as spare filters and treatment chemicals

Ensure access to back-up power generation

Take precautions to keep ash out of water supply equipment:

- close water supply intakes before turbidity levels become excessive
- consider adding coagulation/flocculation agent to reduce turbidity
- cover filter beds and clarifiers
- protect other exposed equipment such as electrical control panels
- maintain clean site to reduce contamination



The following resources provide further information on volcanic hazards:
<http://www.nzta.govt.nz>
<http://www.civildefence.govt.nz>
<http://www.fire.govt.nz>
 Drafted by Carol Stewart, Tom Wilson & David Johnson, 27 February 2010

VOLCANIC ERUPTION RECOMMENDED ACTIONS FOR ROADING MANAGERS

VOLCANIC ASH

Ash dispersal is dependent on prevailing wind direction.

Silt to sand size, Highly Abrasive, mildly Corrosive, potentially Conductive

May be ingested into engines, blockage lines and stranding the engine and other mechanical parts.

Ash may contaminate areas for extended periods of time (don't touch the ash) and its fine granules can make it difficult to handle compared to sand.

Thick ashfalls may create extra loading on bridges (ash is very heavy).

Driving Hazards:

- Early on-mobility by wind, water, and frost moving vehicles.
- During Hazards, only slippery surfaces, check road markings, poor visibility during ashfall.
- Respiratory hazard (easily ingested by humans and animals).



REDUCTION

Volcanic eruptions may have a rapid onset, so emergency planning needs to be done well in advance.

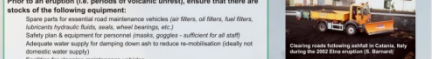
Develop a Volcanic Hazard Management Plan

- Identify a hierarchy of roads for priority of clean-up.
- Identify ash disposal sites and coordinate road closures.
- Ensure road maintenance equipment is available.
- Regularly review plan to ensure it is up to date.

READINESS

Prior to an eruption (i.e. periods of volcanic unrest), ensure that there are stocks of the following equipment:

- Spare parts for essential road maintenance vehicles (air filters, fuel filters, alternators, wiper blades, wheel bearings, etc.)
- Safety plan & equipment for personnel (rescue, goggles - sufficient for all staff)
- Adequate water supply for cleaning (don't wash ash reduce re-ventilation (don't use domestic water supply))
- Facilities for cleaning maintenance vehicles.
- Establish ash disposal site (in consultation with Territorial Local Authority).



RESPONSE

ACTIVATE emergency plan

- health and safety plan
- Identify priority roads for clearance
- monitor eruption information (www.geonet.org.nz)
- monitor weather conditions (obtain where ash will be deposited)
- be prepared to distribute information to other road users on best practices
- Clearly monitor performance of maintenance vehicles and health of staff

RECOVERY

Equipment should be cleaned as often as possible to mitigate damage.

Ensure ash is disposed of in an appropriate manner.

An on-going eruption & re-mobilised ash may continue to re-contaminate roads long after the eruption.

Plan for long term management of ash clearance and disposal from sediment capture devices.

long term supply arrangements of protective and spare parts may be required.

Further information on dealing with volcanic ash may be found in the following locations:
<http://www.geonet.org.nz>
<http://www.nzta.govt.nz>
<http://www.civildefence.govt.nz>
<http://www.fire.govt.nz>
 Drafted by Tom Wilson

VOLCANIC ERUPTION RECOMMENDED ACTIONS FOR AIRPORTS

REDUCTION

Develop a Volcanic Hazard Management Plan

- Ensure this includes designated ash disposal sites.
- Regularly review plan to ensure it is up to date.
- Conduct regular exercises and training

READINESS

If warning is given that an eruption may occur, ensure stocks of the following equipment are available:

Tarpaulins / Plastic sheeting

- Sufficient quantities to cover vulnerable parts of aircraft grounded during the eruption, i.e. windshields, nose cones, engine intakes, wheel assemblies.
- Further quantities to cover any machinery tail outside.

Adhesive duct tape

- Sufficient quantities to secure plastic sheeting to aircraft/machinery, sealing at edges.

Spare parts for essential vehicles and machinery

- Air filters, oil filters, fuel filters, hydraulic fluids, wiper blades, wheel bearings, etc.
- Use plastic sheeting/tarpaulins and adhesive (duct) tape.
- Additional rags, vacuum cleaner bags, shovels, brooms.

Filtration / dust masks and goggles

- Sufficient masks for all involved staff for at least one week.
- Sufficient goggles for workers cleaning up ash.
- Adequate harnesses to secure workers to slippery roofs.
- Prior to ashfall establish a site where ash may be dumped.

RESPONSE

Should an ash plume be generated that is likely to impact the airport, the following steps should be taken:

Activate Emergency teams. Business and safety issues are identified for all personnel.

Decide: Fly aircraft out, cover aircraft.

Immediately confirm which aircraft are to remain grounded.

Grounded Aircraft

- Need to have vulnerable parts covered.
- Immediately confirm which aircraft are to remain grounded.
- Vulnerable parts include windshields, pilot cabins, nose cones, engine intakes, wheel assemblies.
- Use plastic sheeting/tarpaulins and adhesive (duct) tape.
- At floor, spacers etc should be fully closed.
- If a significant ashfall is expected (> 50cm), anchor any aircraft to the ground at the nose that have:
 - engines at the tail
 - large surface areas (i.e. horizontal stabilizers) at rear of aircraft.

RECOVERY

Volcanic ash is highly abrasive and can be extremely corrosive

- Take this into account when cleaning (especially aircraft)
- clean aircraft as quickly as possible to mitigate corrosion.

Some use of systems that re-circulate interior air may be possible during ashfall (except admission to fan blades, bearings etc.)

Clear runways frequently during a long-term eruption to prevent ash accumulating (especially wide-span hangar-type roofs)

Check navigation systems and friction test of the runway

Further information on dealing with volcanic ash may be found in the following locations:
<http://www.geonet.org.nz>
<http://www.nzta.govt.nz>
<http://www.civildefence.govt.nz>
<http://www.fire.govt.nz>
 Drafted by Tom Wilson

Contributing to international resources



NEW Ash-Impacts Website

VOLCANIC ASH
WHAT IT CAN DO AND HOW TO PREVENT DAMAGE

[Partners](#)

[Agriculture](#) | [Buildings](#) | [Communication](#) | [Health](#) | [Power Supply](#) | [Transportation](#) | [Water Supply](#) | [Waste Water](#)

[Click a category above for effects of ash and how to reduce its impacts](#) [Search](#)

What is Volcanic Ash?

 Volcanic ash consists of tiny jagged pieces of rock and glass. Ash is hard, abrasive, mildly corrosive, conducts electricity when wet, and does not dissolve in water. Ash is spread over broad areas by wind.

[\[Ash properties & ash distribution\]](#)

What is it like during ash fall?

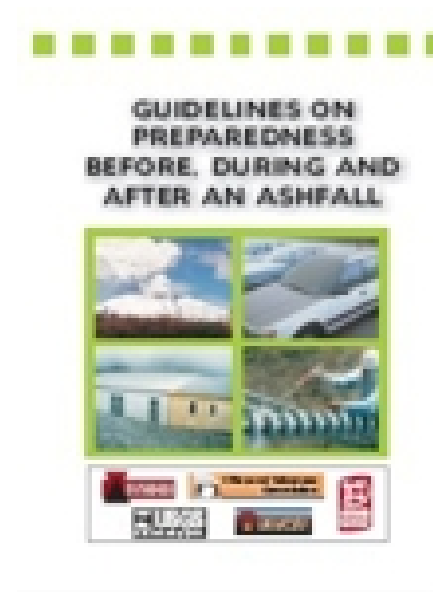
 Falling ash can turn daylight into complete darkness. Accompanied by rain and lightning, the gritty ash can lead to power outages, prevent communications, and disorient people.

[\[Images & description of ash fall?\]](#)



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<http://volcanoes.usgs.gov/ash/>



**GUIDELINES ON
PREPAREDNESS
BEFORE, DURING AND
AFTER AN ASHFALL**



**THE HEALTH HAZARDS
OF VOLCANIC ASH
A guide for the public**



QUESTIONS?

Ashfall mitigation measures for
livestock during the 2006 Ubinas
eruption, Peru

