Volcanic unrest at Taupō, New Zealand, 2022-23

Steven Sherburn and Volcano Monitoring Group
EOS-NTU volcano-seismic data workshop, November 2025

Earth Sciences New Zealand

Published paper on Taupō 2022-23 seismic unrest

doi:10.26443/seismica.v3i2.1125

SEISMICA

Seismic characteristics of the 2022-2023 unrest episode at Taupō volcano, Aotearoa New Zealand

Oliver D. Lamb [*1], **Stephen Bannister** [2], **John Ristau** [2], **Craig Miller** [1], **Steve Sherburn** [1], **Katie Jacobs** [2], **Jonathan B. Hanson** [2], **Elisabetta D'Anastasio** [2], **Sigrún Hreinsdóttir** [2], **Eveanjelene Snee** [2], **Mike Ross** [2], **Eleanor R. H. Mestel** [3], **Finnigan Illsley-Kemp** [3]

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Abstract Taupō is a large caldera volcano located beneath a lake in the centre of the North Island of New Zealand and most recently erupted ~1800 years ago. The volcano has experienced at least 16 periods of unrest since 1872, each of which was characterised by increased seismic activity. Here we detail seismic activity

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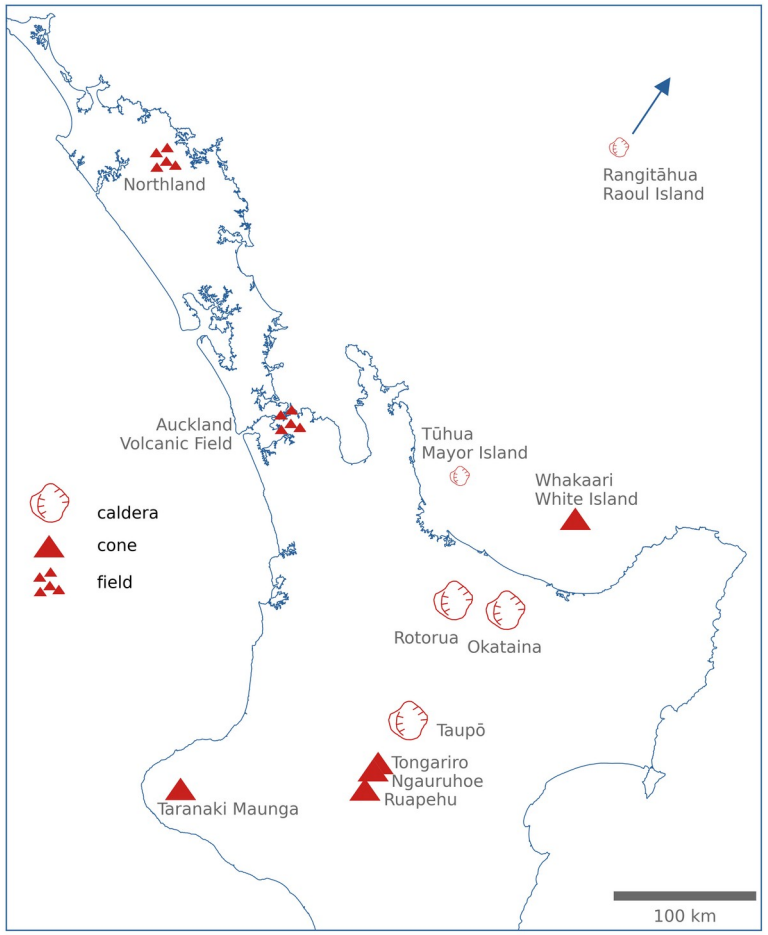
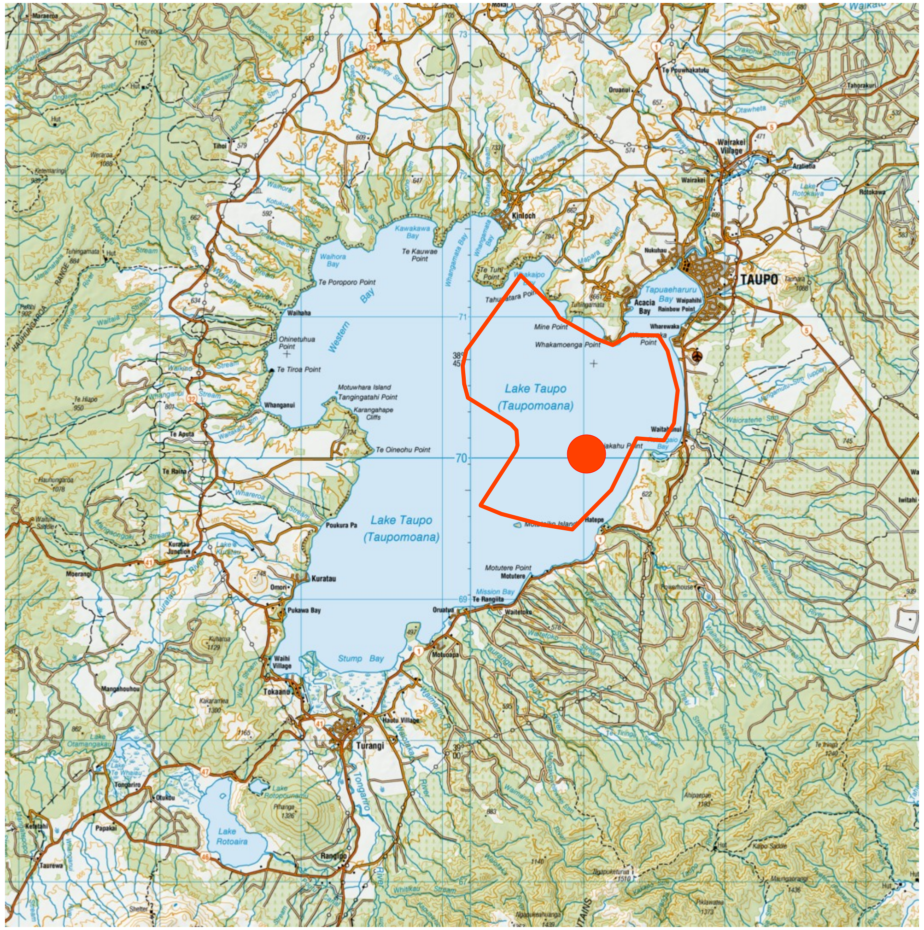
New Zealand volcanism



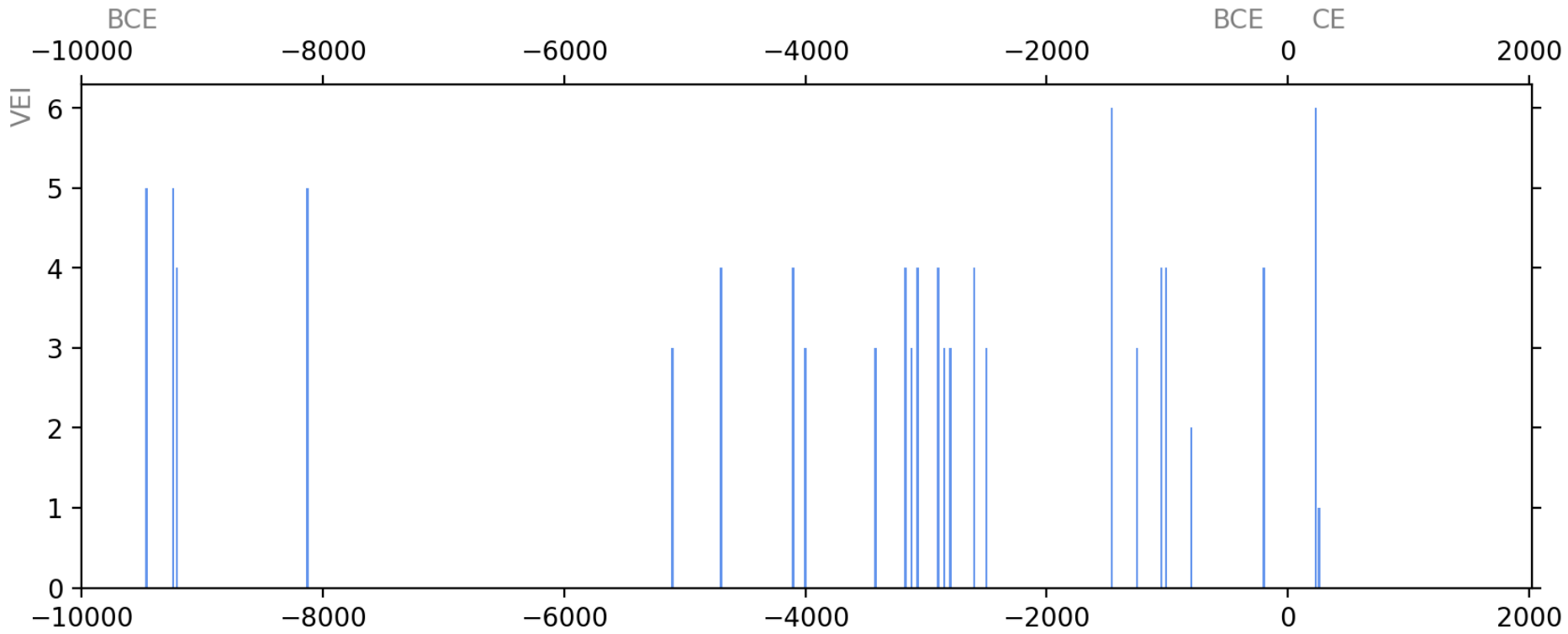
- Cones
- Calderas
- Volcanic fields

Taupō volcano



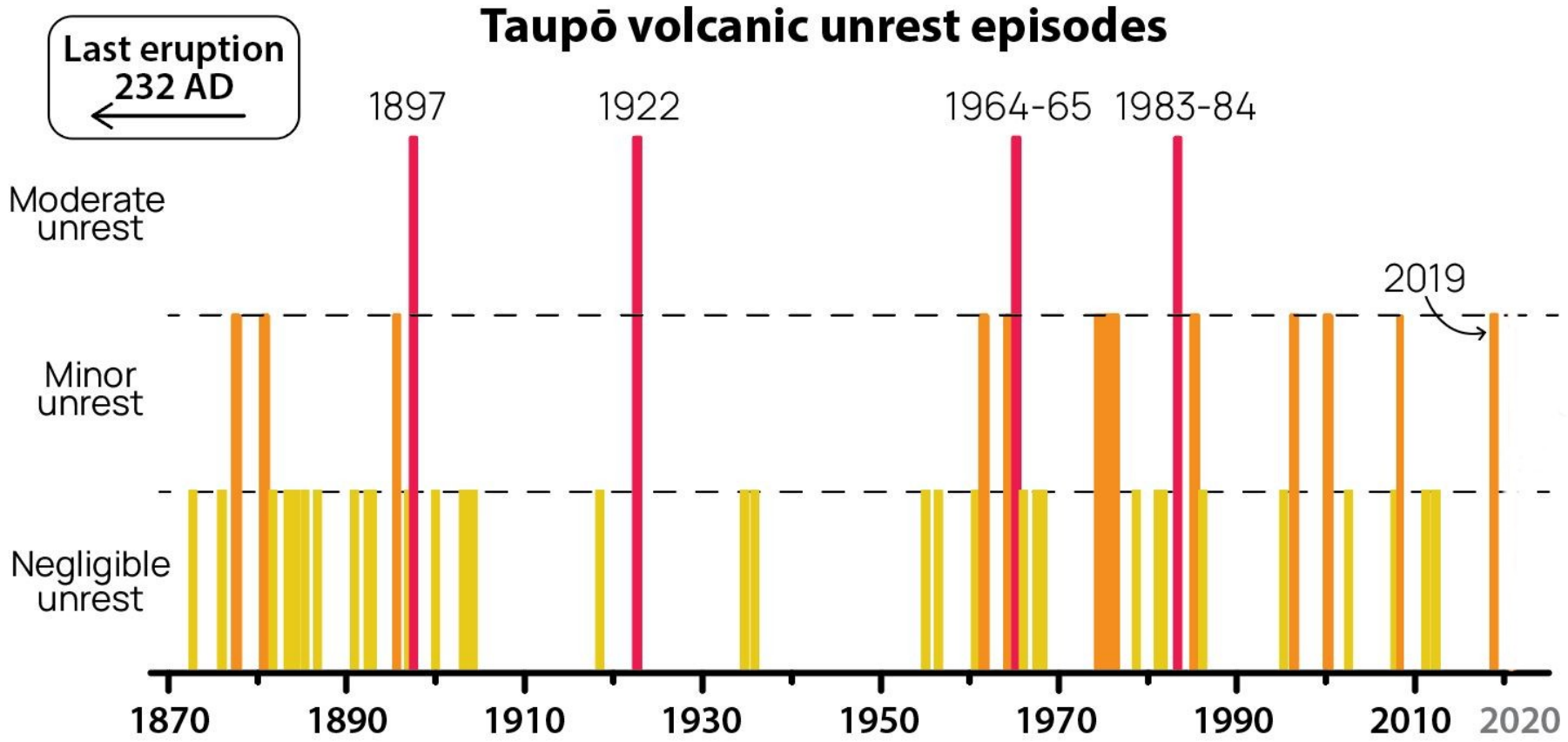
30 km

Taupō eruption history

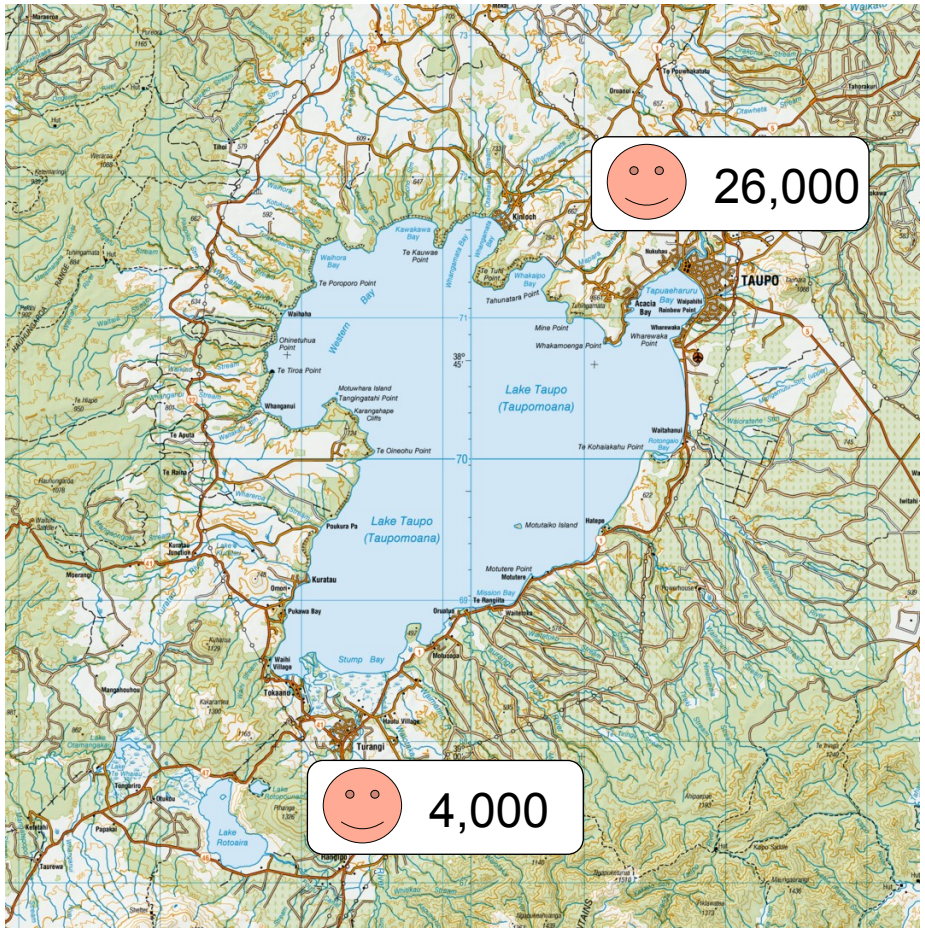


Smithsonian GVP VEI data

History of volcanic unrest, before 2022-23

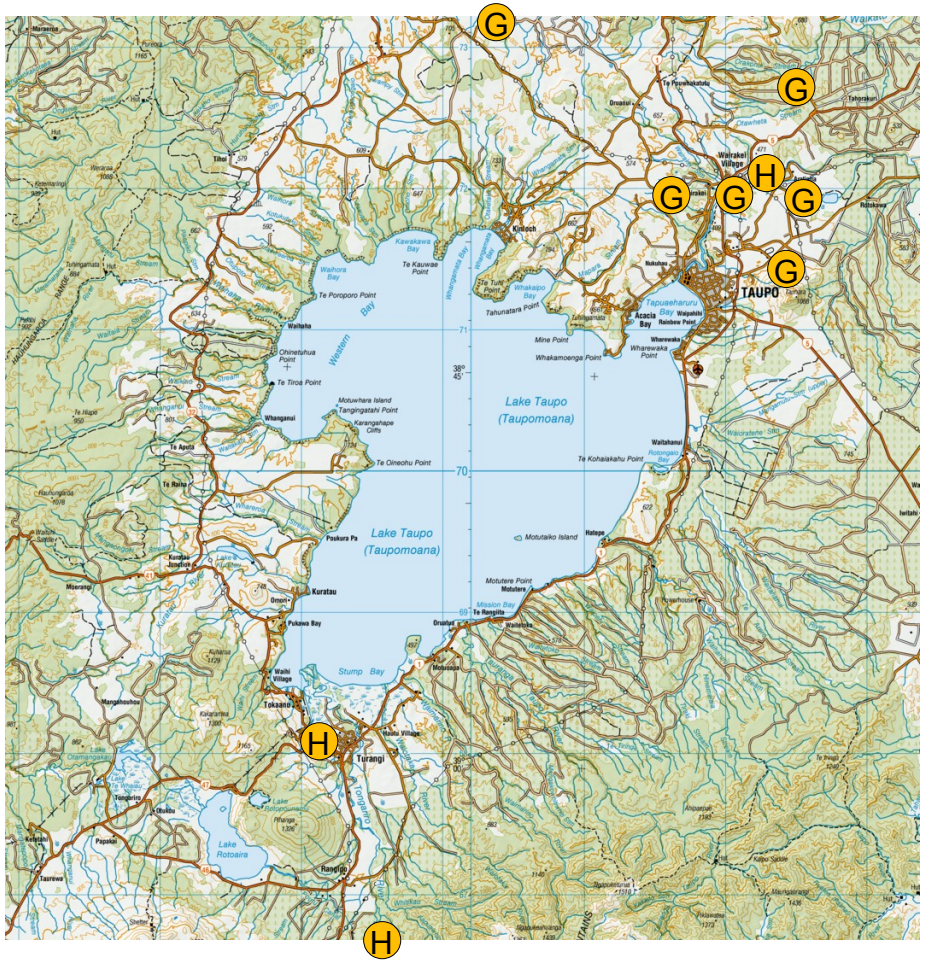


Community



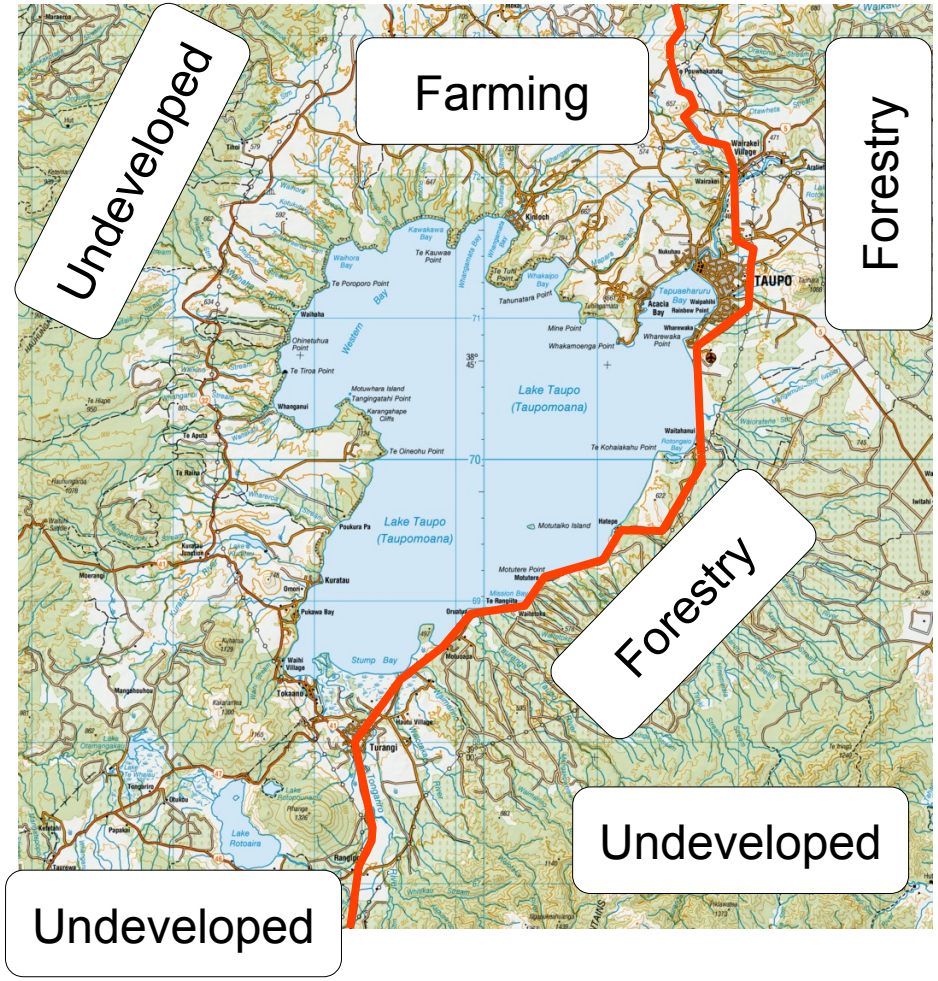
- District population 42,000
- Annual tourism visitors ~1 million

Community



- Electricity power stations
- Geothermal G
- Hydroelectric H

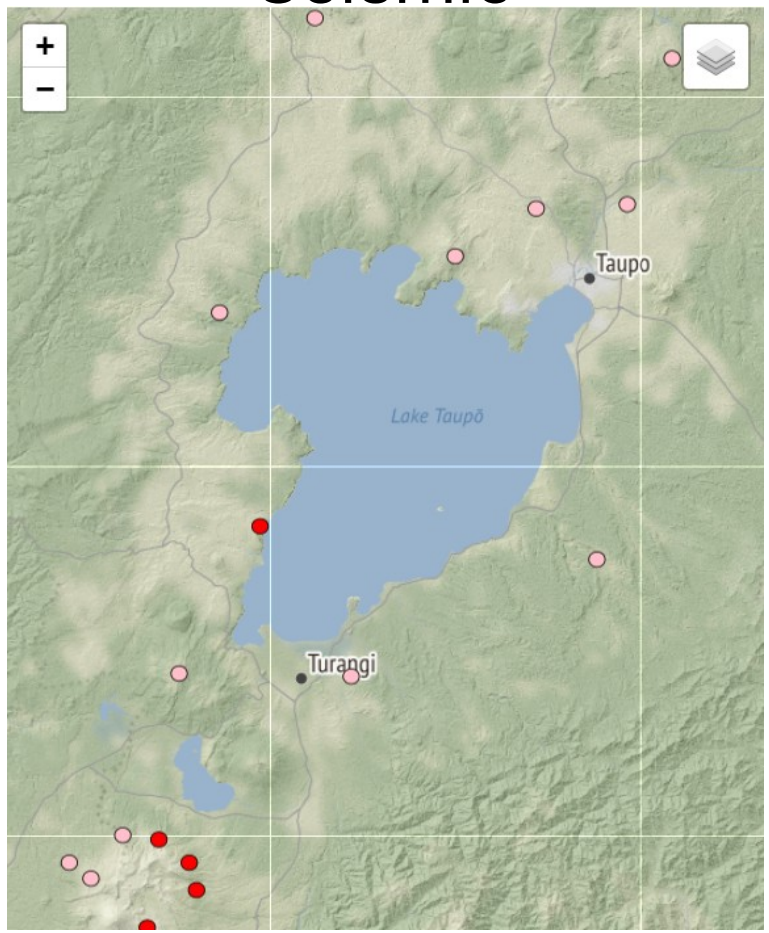
Community



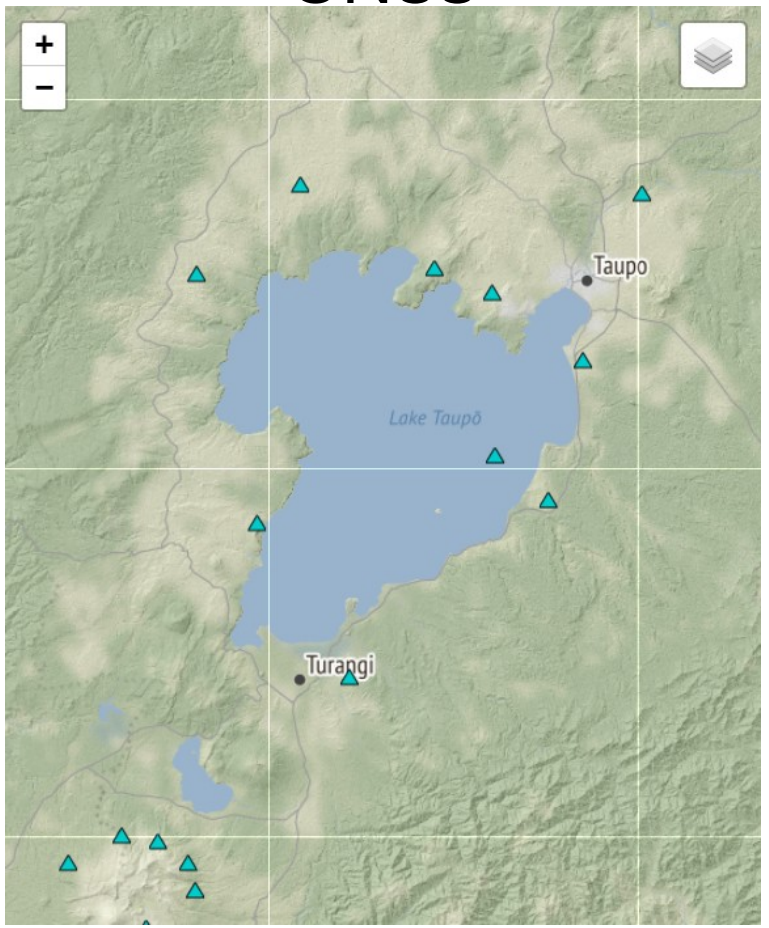
- Major highway and land use

Monitoring network, May 2022

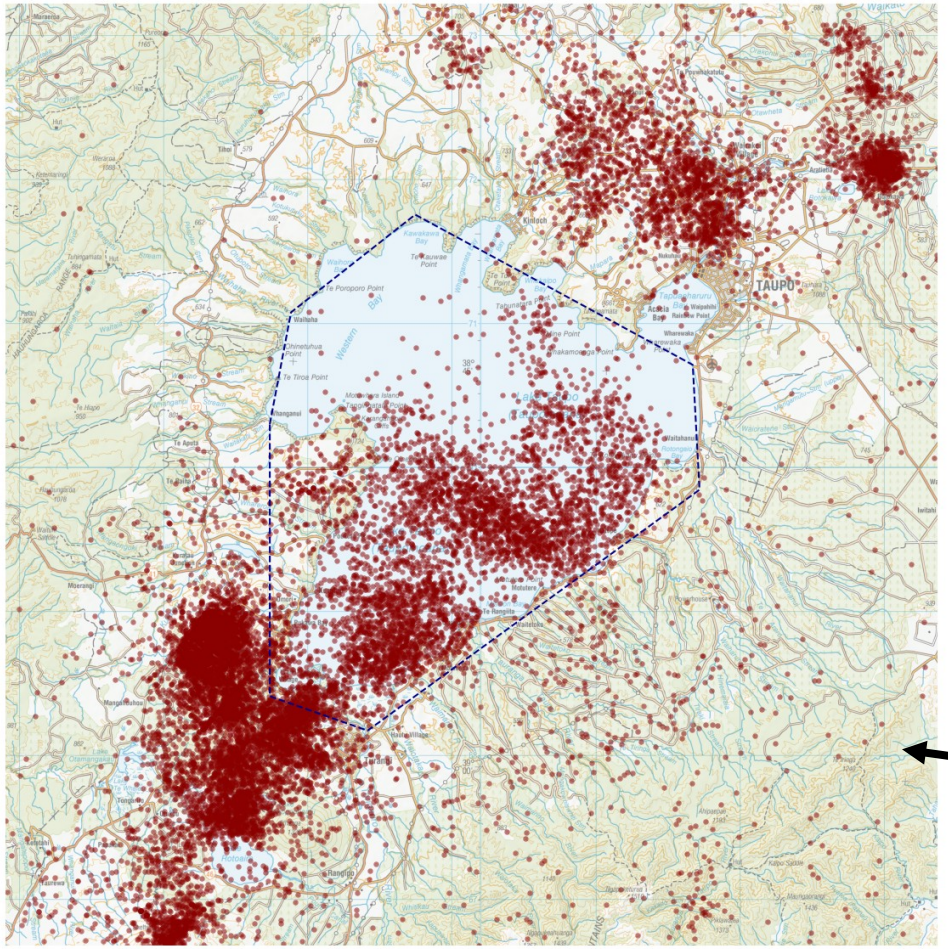
Seismic



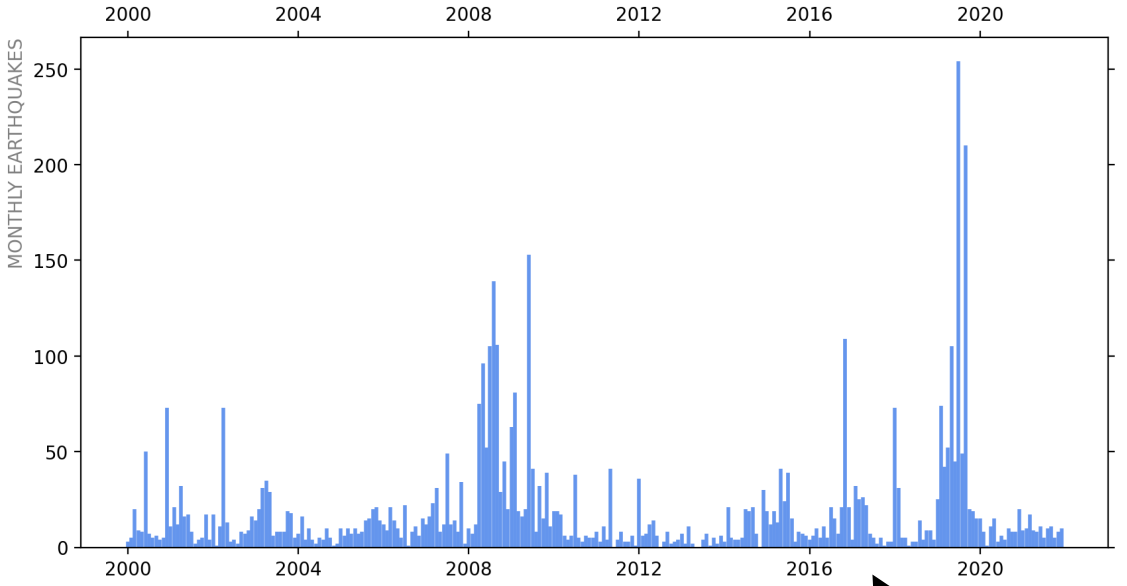
GNSS



Historic seismicity, 2000 - 2021

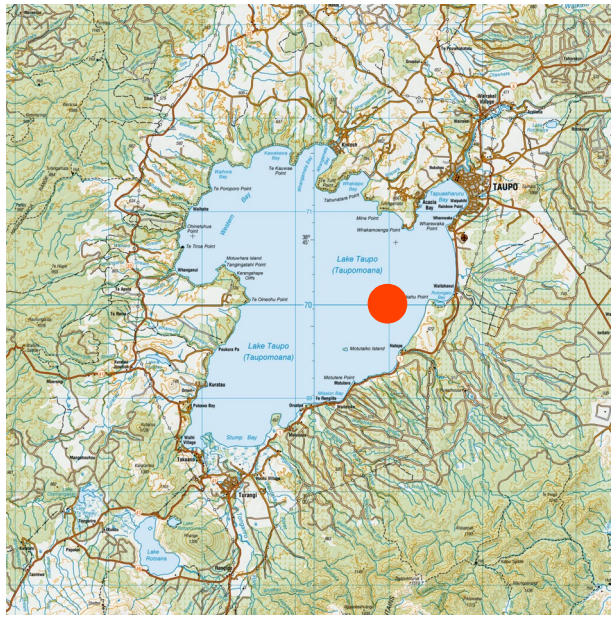


16,000



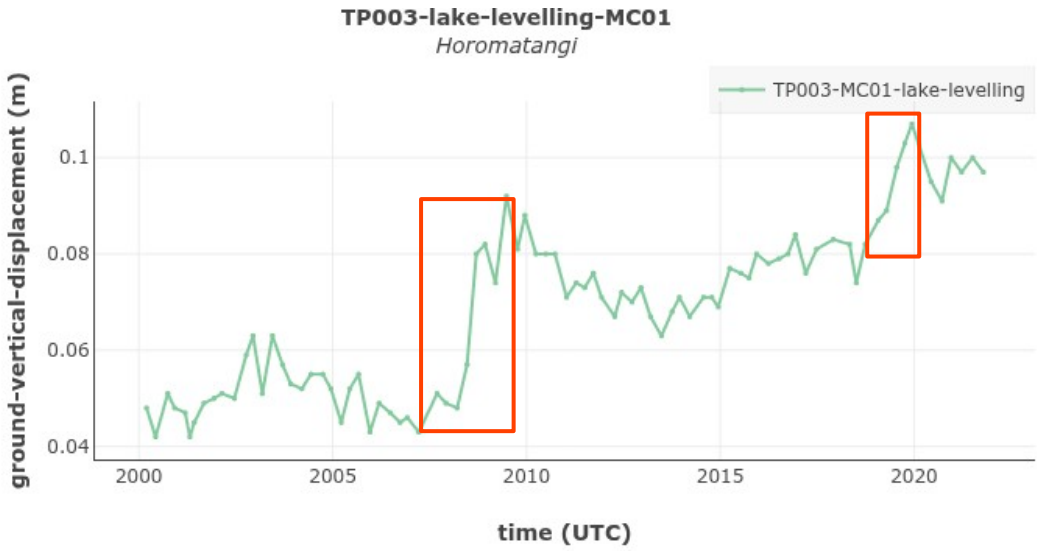
5,000

Historic deformation, within caldera



Historic deformation, within caldera

Levelling



GNSS

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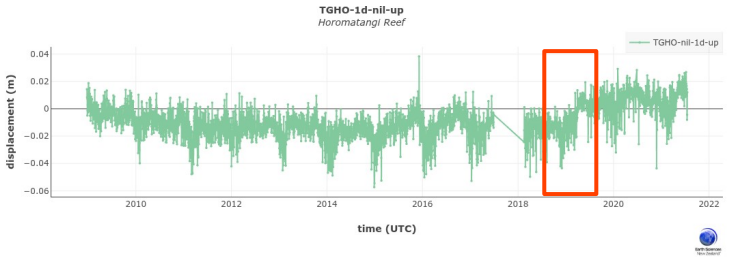
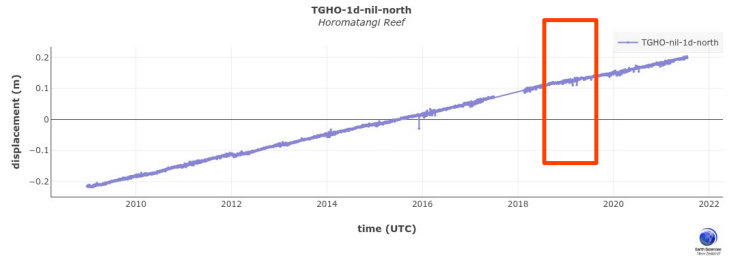
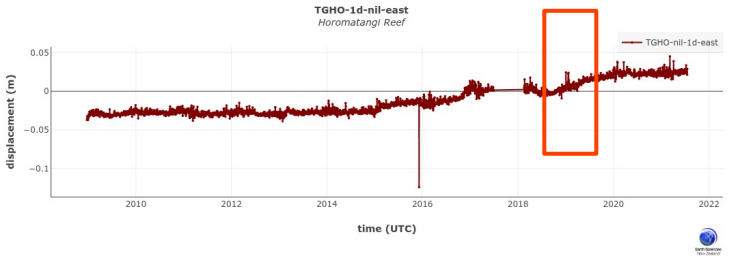


N



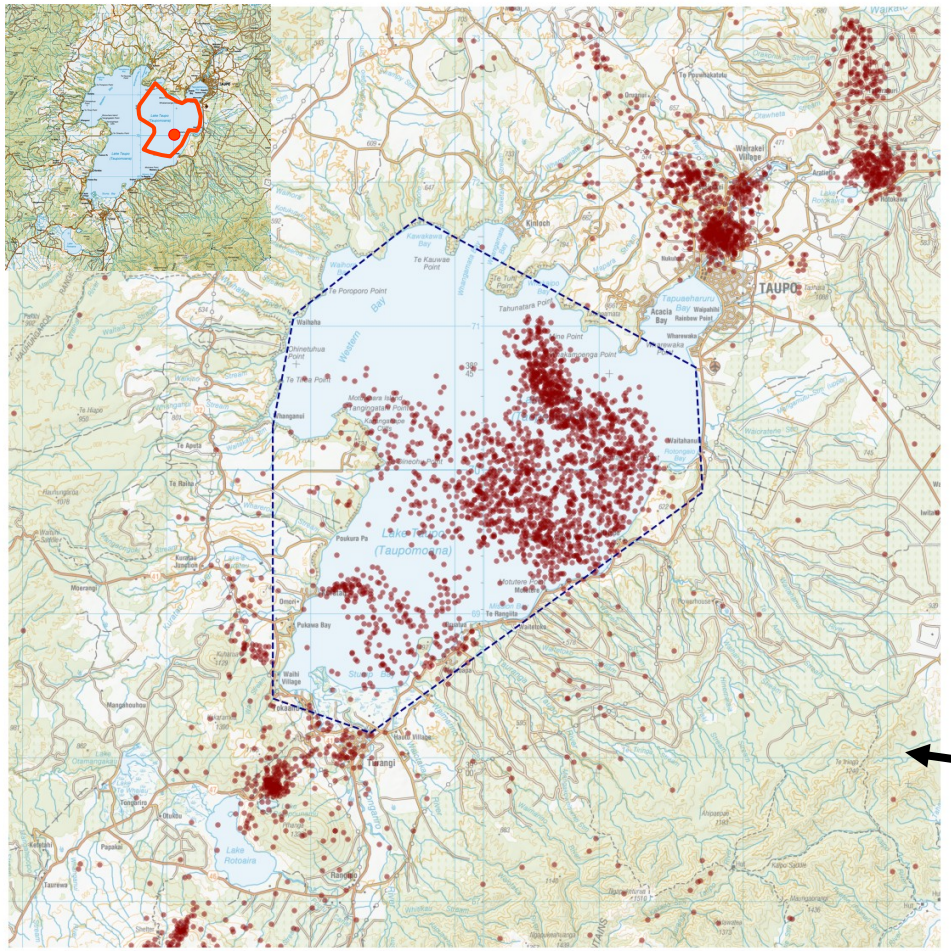
E



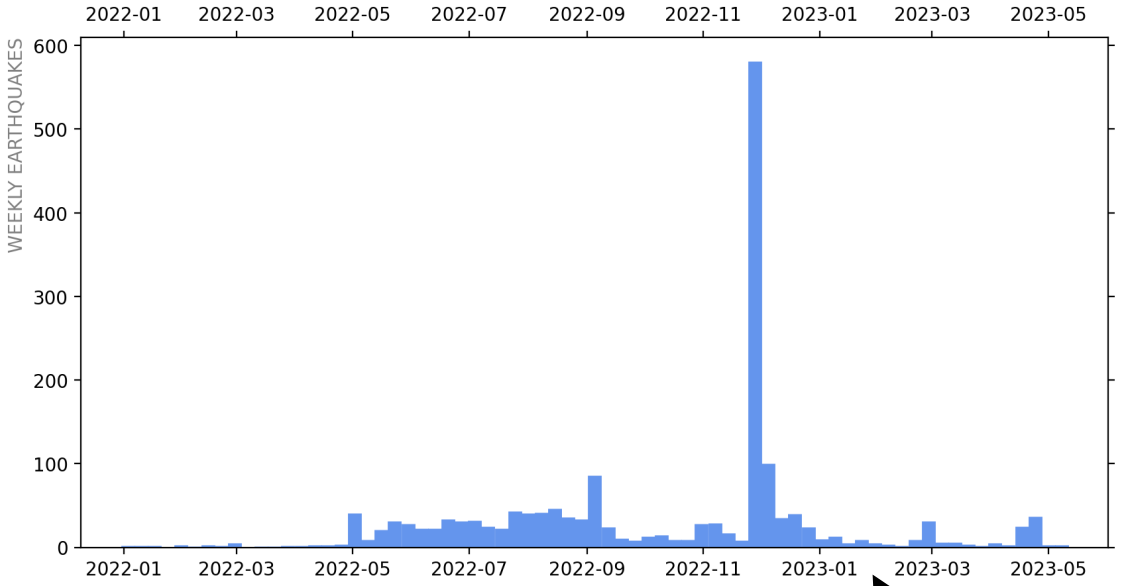
2022-23 unrest

- Seismicity
- Deformation
- Hot springs sampled – no change

Seismic activity, 2022-23

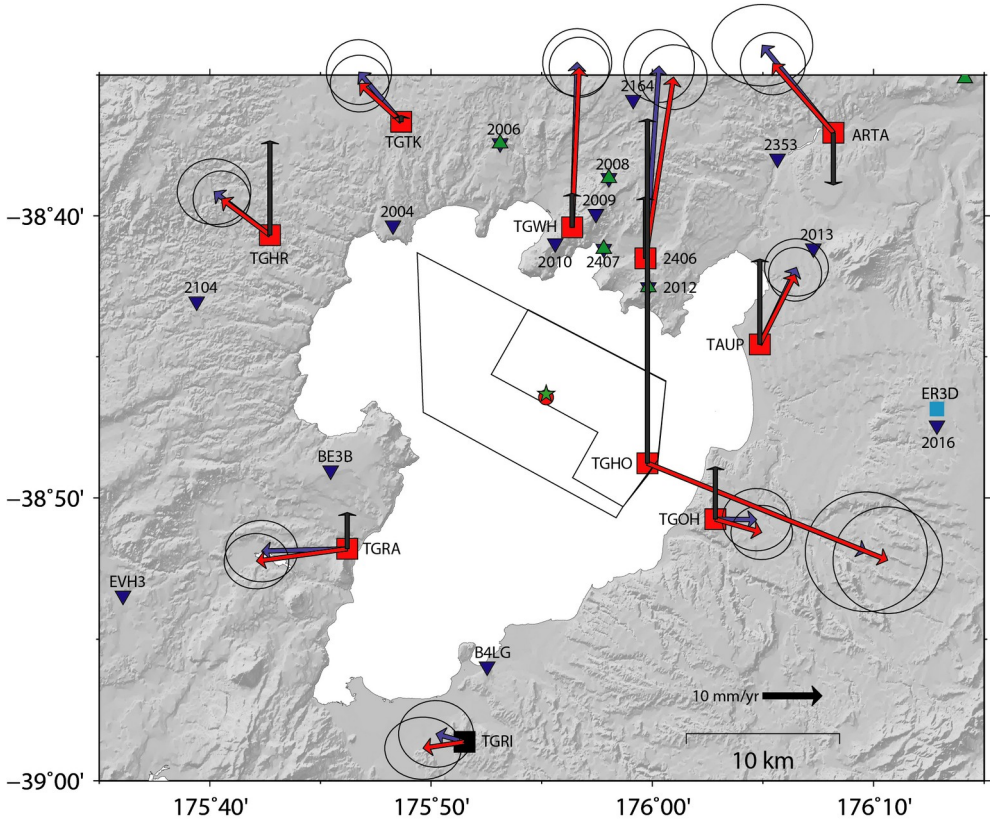


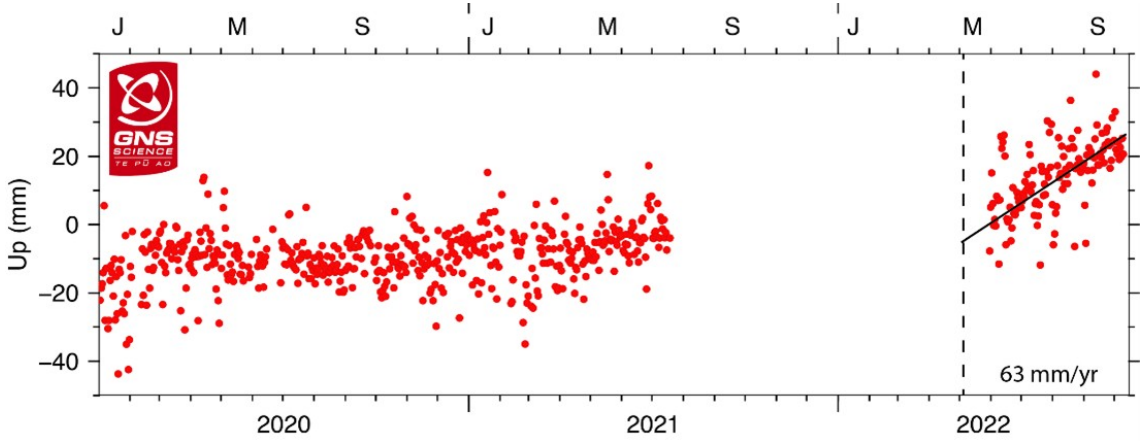
2,300

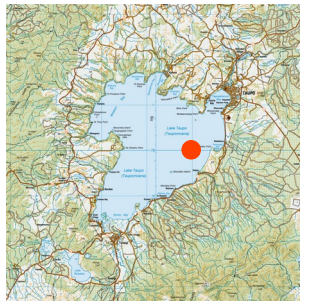


1,800

Deformation, 2022-23





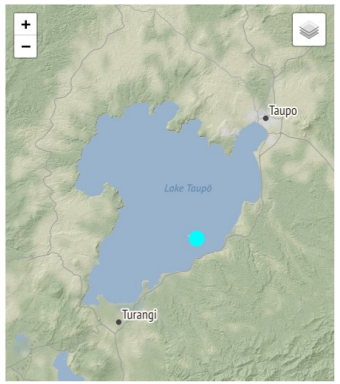


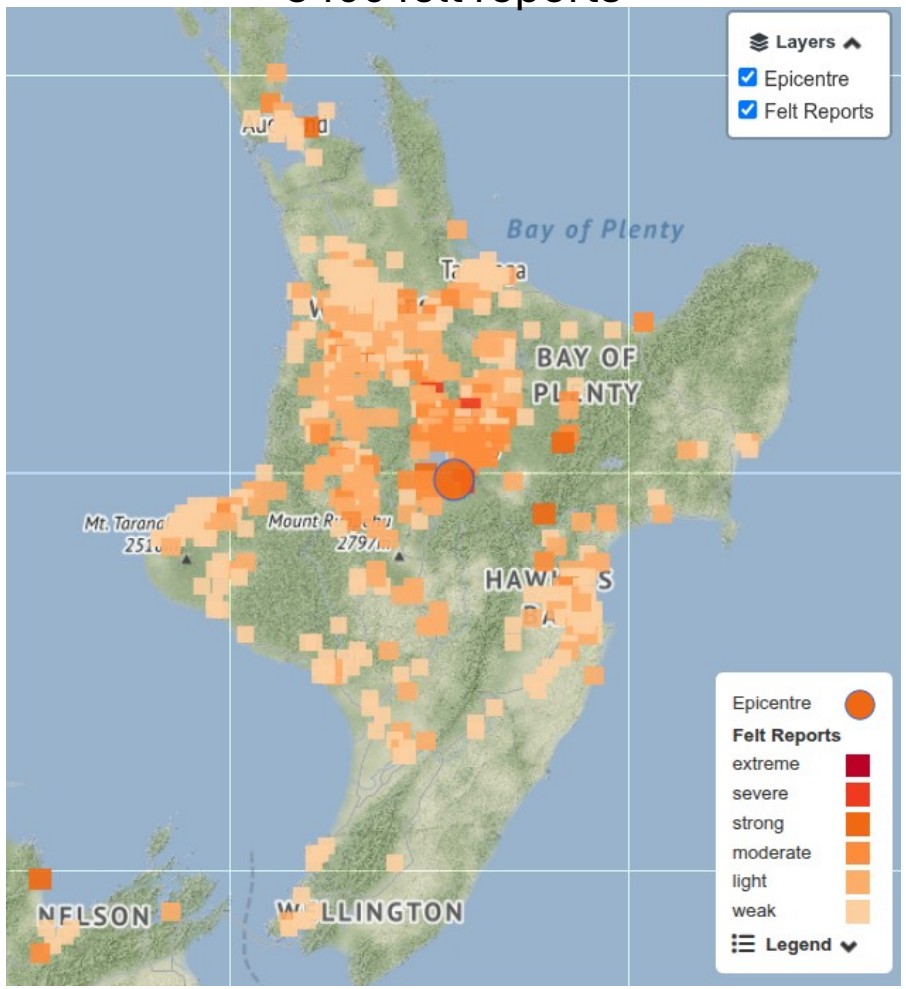
Map 2022 September

Time-series published in VAB 2022-11-16

M_L5.7 earthquake, 11:47 PM, 30 November 2022

5400 felt reports





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- Largest historically beneath lake

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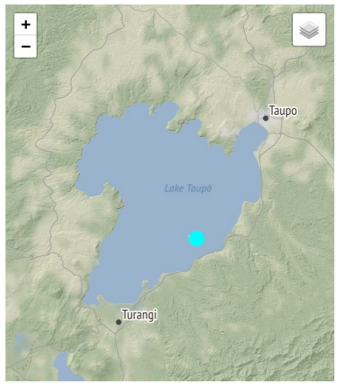
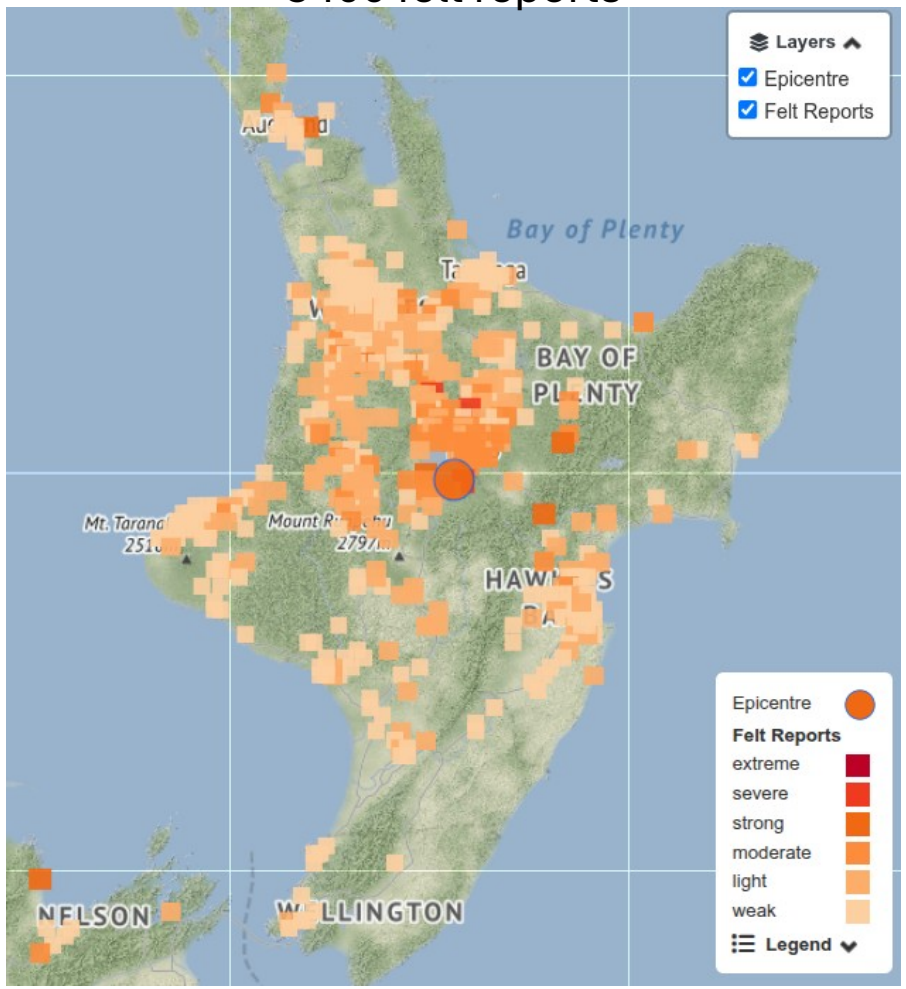
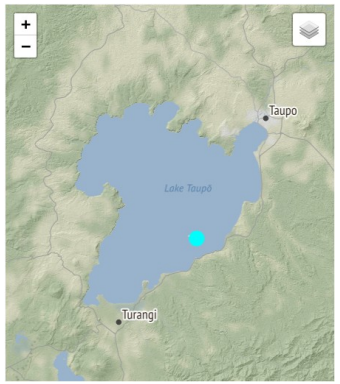




M_L5.7 earthquake, 11:47 PM, 30 November 2022

- Largest historically beneath lake
- Depth 9±5 km
- PGA = 0.1g
- Non-double couple component



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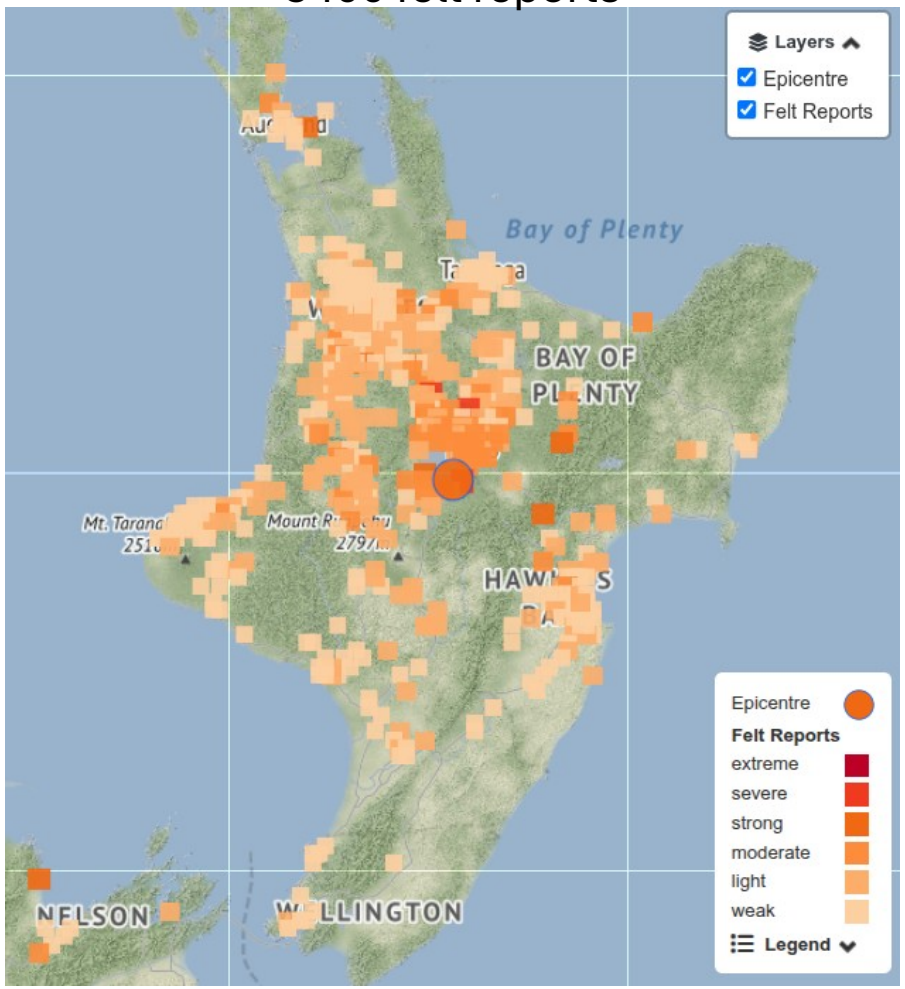

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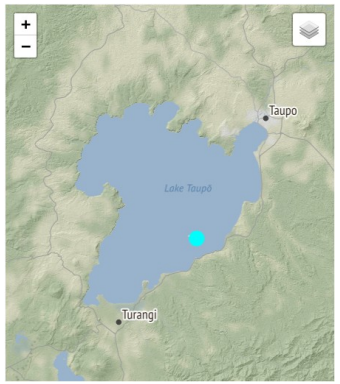
- Lakeshore landslides
- Small tsunami



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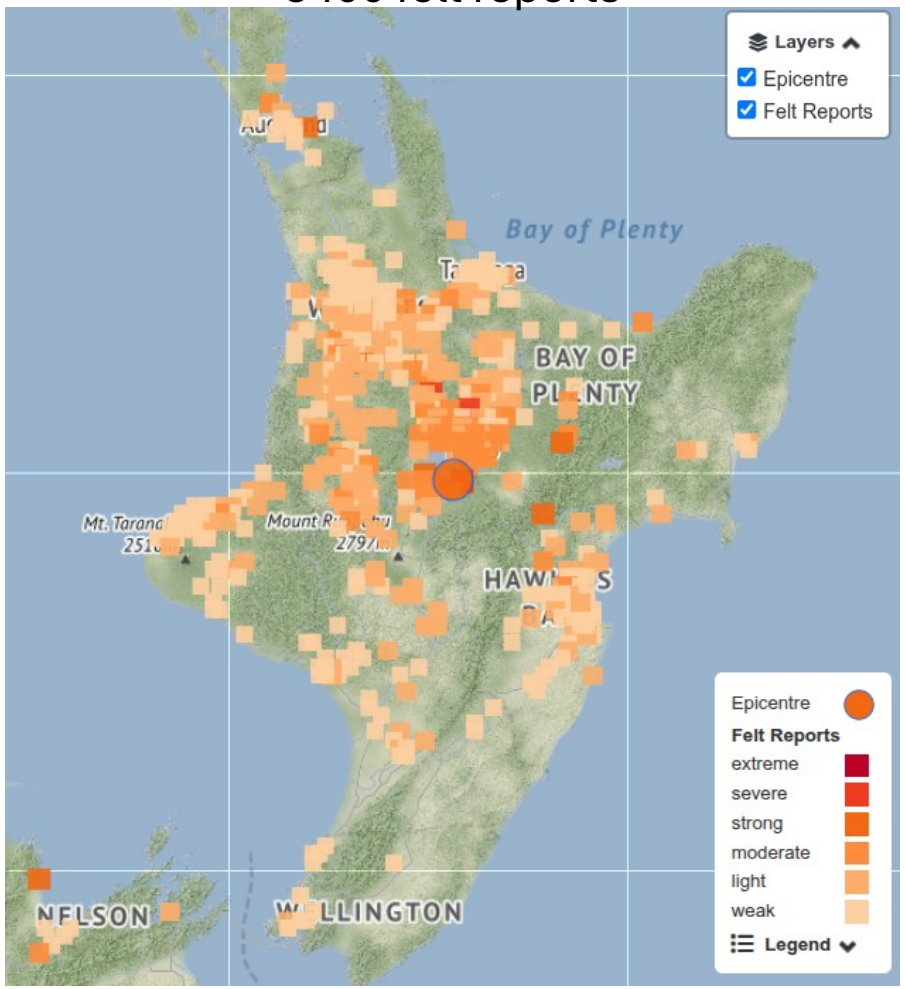

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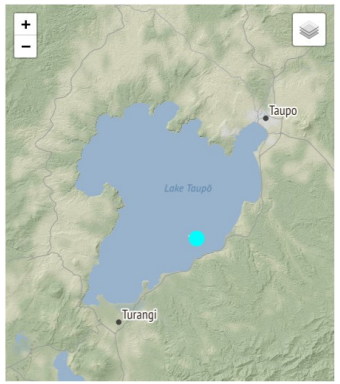
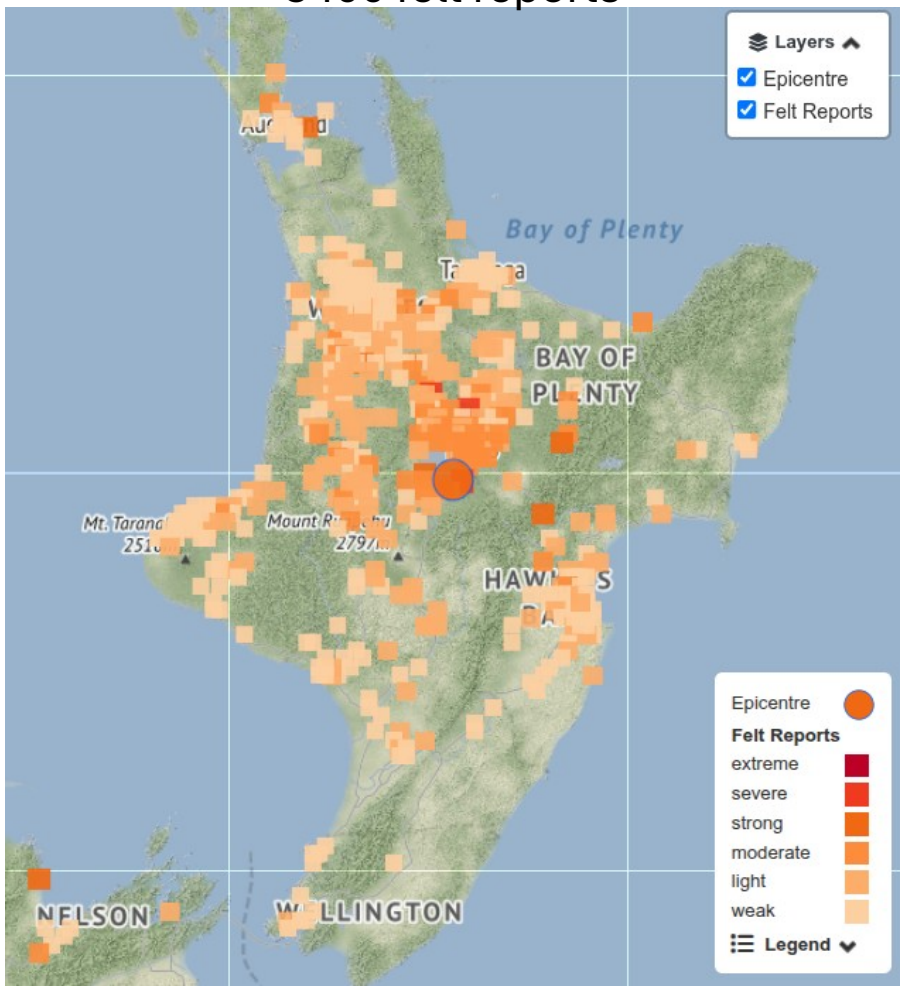


- 3 x M_L4.2-4.5 aftershocks
- Previously, M_L4.2, 2022-09-10

5400 felt reports



Earthquake effects

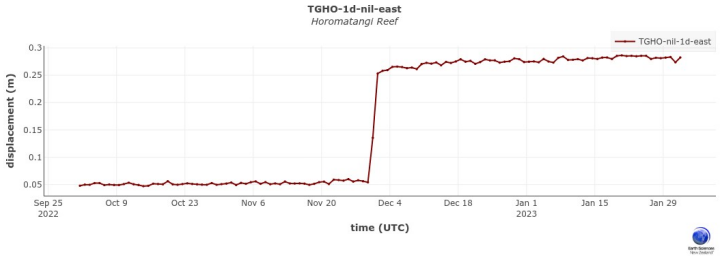
U

over 2 days
17.8 cm

N

16.2 cm

E



19.9 cm

Tsunami caused by landslide + lake floor uplift

Unrest model

- Primary event is inflation, due to ‘unseen’ intrusion
- Which triggered seismicity around existing caldera structures

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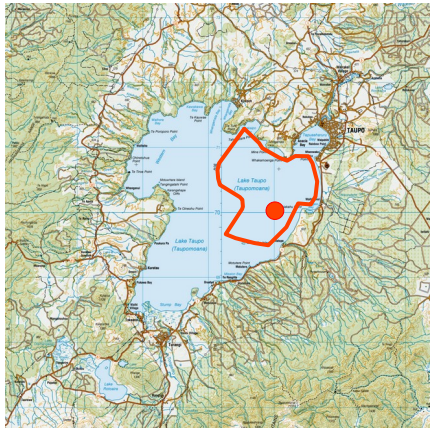

Seismic data issues and difficulties

- Earthquake depth poorly resolved
  - More than 50% fixed at 5 or 10 km – too far from nearest station

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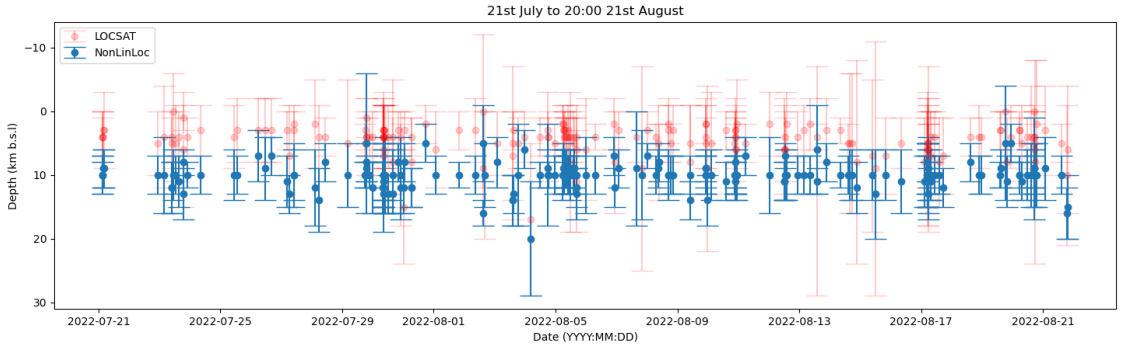
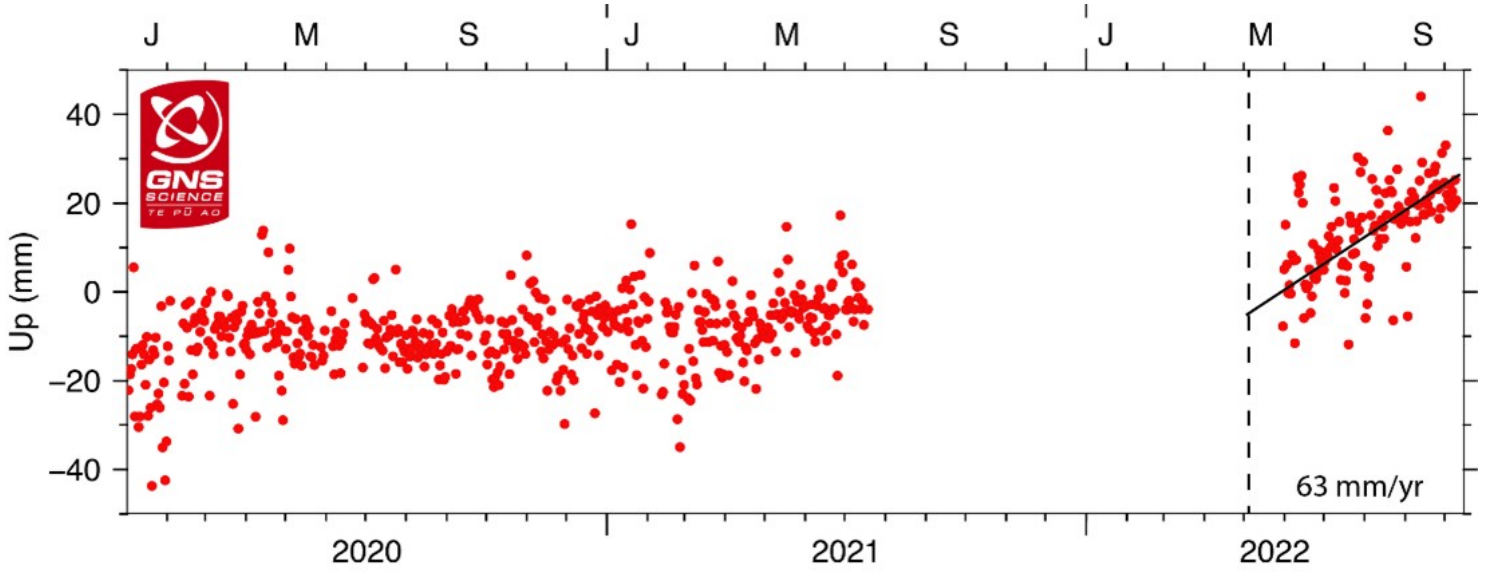
- Earthquake depth poorly resolved
  - More than 50% fixed at 5 or 10 km – too far from nearest station
- Velocity model not suitable
  - IASP91 used

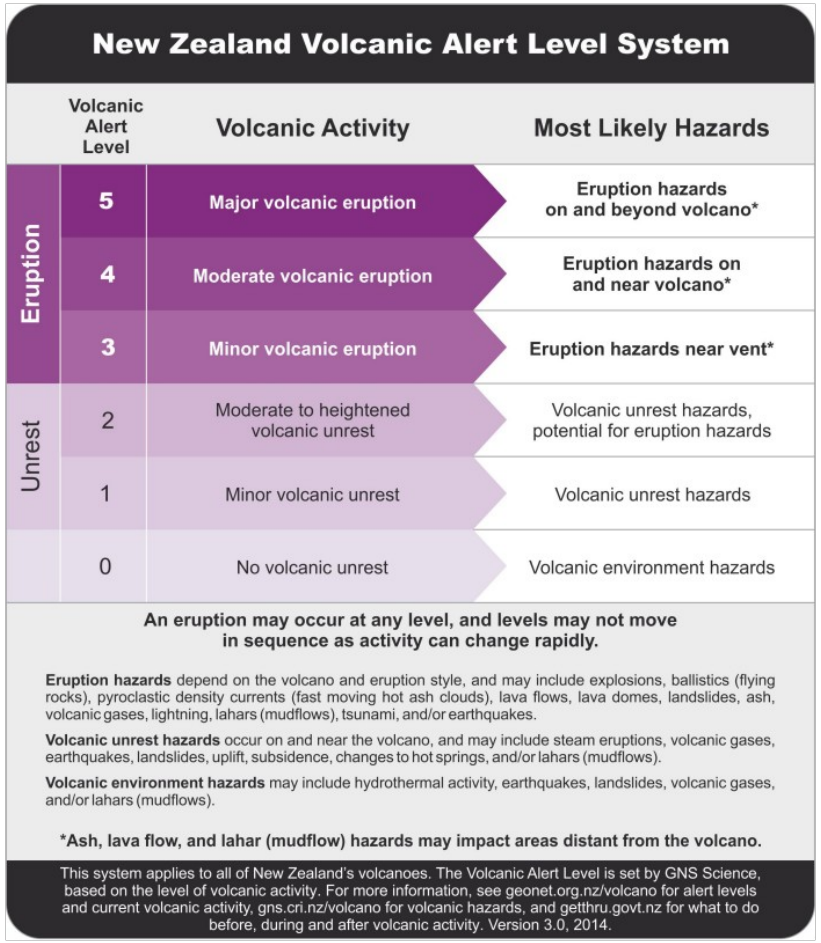


GNSS data issues

- Key station not operating at start of unrest
- Data noisy



Volcanic Alert Level (VAL)



New Zealand Volcanic Alert Level System

	Volcanic Alert Level	Volcanic Activity	Most Likely Hazards
Eruption	5	Major volcanic eruption	Eruption hazards on and beyond volcano*
Eruption	4	Moderate volcanic eruption	Eruption hazards on and near volcano*
Eruption	3	Minor volcanic eruption	Eruption hazards near vent*
Unrest	2	Moderate to heightened volcanic unrest	Volcanic unrest hazards, potential for eruption hazards
Unrest	1	Minor volcanic unrest	Volcanic unrest hazards
	0	No volcanic unrest	Volcanic environment hazards

An eruption may occur at any level, and levels may not move in sequence as activity can change rapidly.

Eruption hazards depend on the volcano and eruption style, and may include explosions, ballistics (flying rocks), pyroclastic density currents (fast moving hot ash clouds), lava flows, lava domes, landslides, ash, volcanic gases, lightning, lahars (mudflows), tsunami, and/or earthquakes.

Volcanic unrest hazards occur on and near the volcano, and may include steam eruptions, volcanic gases, earthquakes, landslides, uplift, subsidence, changes to hot springs, and/or lahars (mudflows).

Volcanic environment hazards may include hydrothermal activity, earthquakes, landslides, volcanic gases, and/or lahars (mudflows).

***Ash, lava flow, and lahar (mudflow) hazards may impact areas distant from the volcano.**

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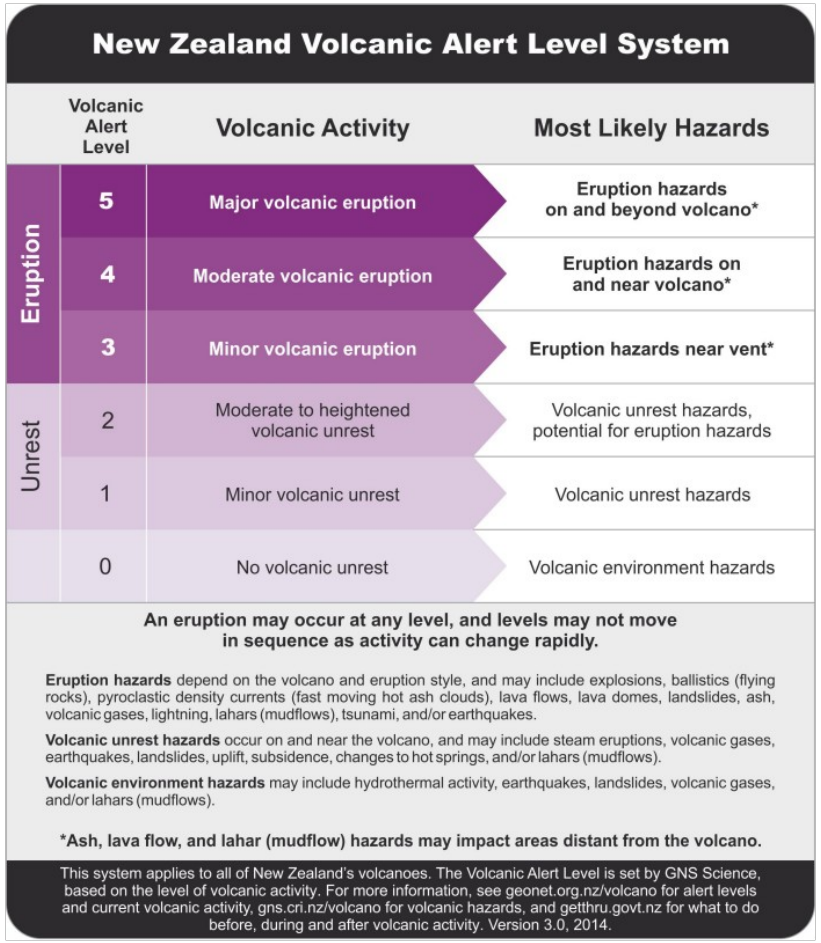

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- Vote by Volcano Monitoring Group (selected members)

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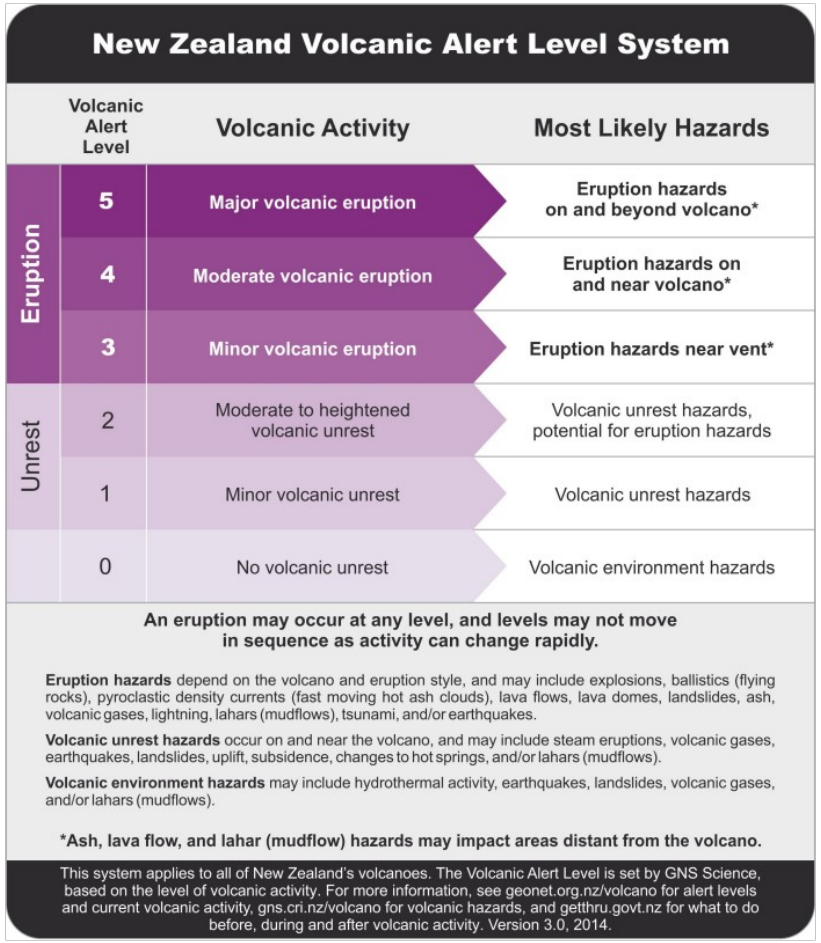

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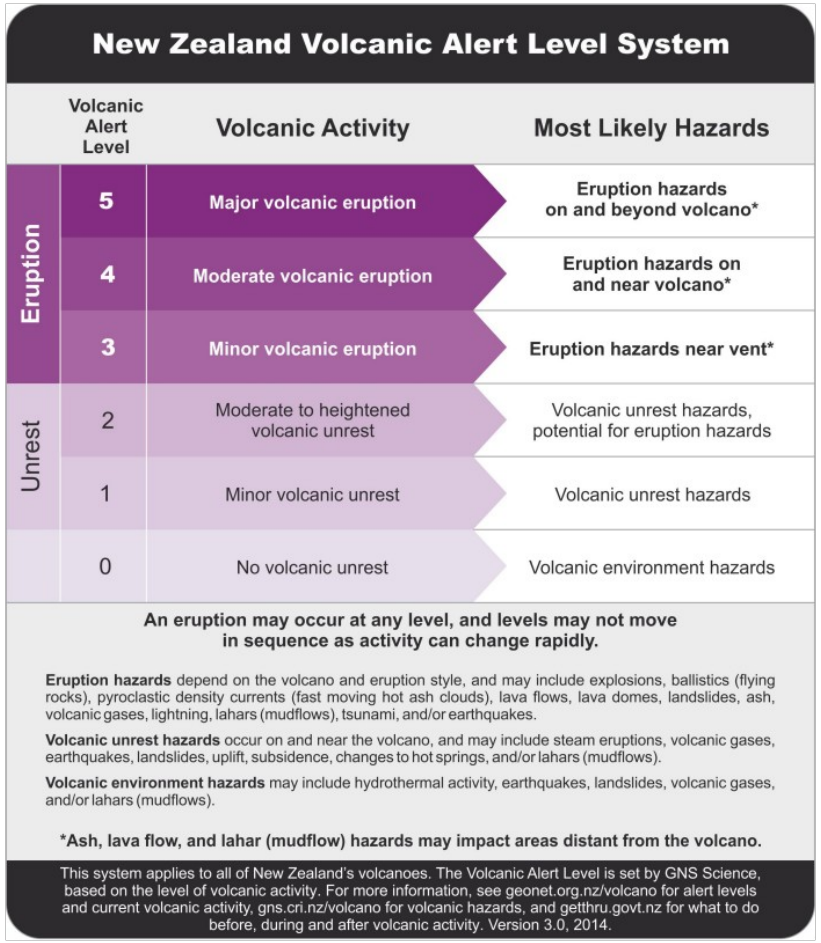
- Vote by Volcano Monitoring Group (selected members)
- Majority vote wins
- Tie decided by VMG chair

Volcanic Alert Level (VAL)



New Zealand Volcanic Alert Level System

	Volcanic Alert Level	Volcanic Activity	Most Likely Hazards
Eruption	5	Major volcanic eruption	Eruption hazards on and beyond volcano*
Eruption	4	Moderate volcanic eruption	Eruption hazards on and near volcano*
Eruption	3	Minor volcanic eruption	Eruption hazards near vent*
Unrest	2	Moderate to heightened volcanic unrest	Volcanic unrest hazards, potential for eruption hazards
Unrest	1	Minor volcanic unrest	Volcanic unrest hazards
	0	No volcanic unrest	Volcanic environment hazards

An eruption may occur at any level, and levels may not move in sequence as activity can change rapidly.

Eruption hazards depend on the volcano and eruption style, and may include explosions, ballistics (flying rocks), pyroclastic density currents (fast moving hot ash clouds), lava flows, lava domes, landslides, ash, volcanic gases, lightning, lahars (mudflows), tsunami, and/or earthquakes.

Volcanic unrest hazards occur on and near the volcano, and may include steam eruptions, volcanic gases, earthquakes, landslides, uplift, subsidence, changes to hot springs, and/or lahars (mudflows).

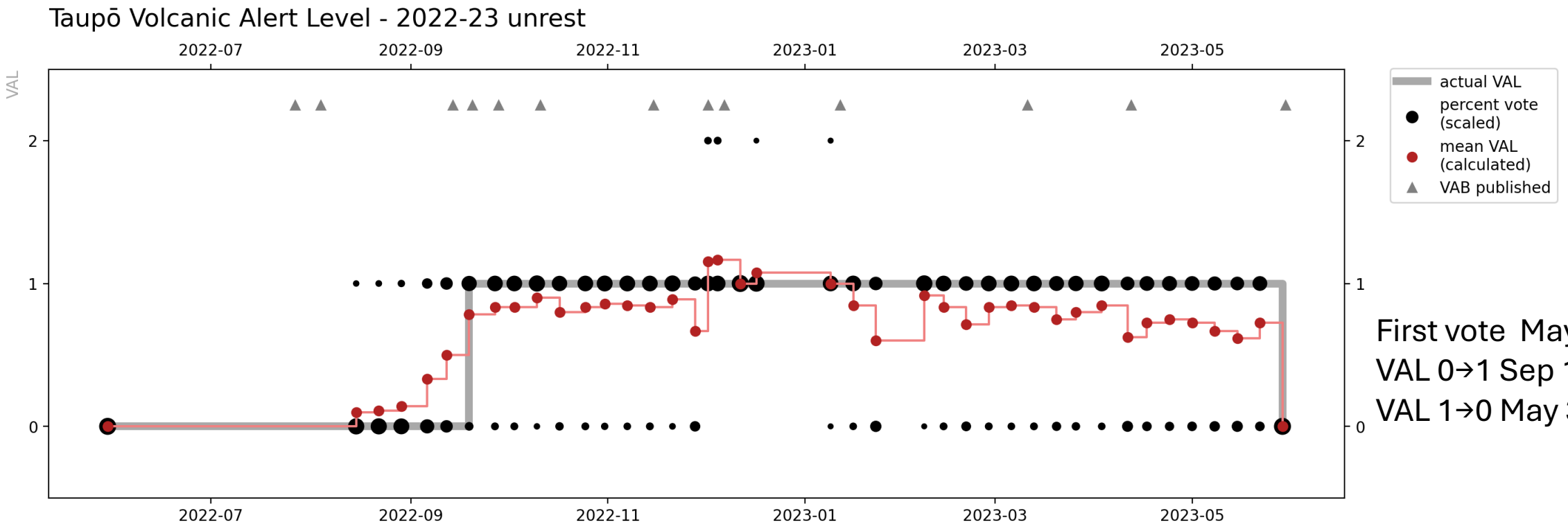
Volcanic environment hazards may include hydrothermal activity, earthquakes, landslides, volcanic gases, and/or lahars (mudflows).

***Ash, lava flow, and lahar (mudflow) hazards may impact areas distant from the volcano.**

This system applies to all of New Zealand's volcanoes. The Volcanic Alert Level is set by GNS Science, based on the level of volcanic activity. For more information, see geonet.org.nz/volcano for alert levels and current volcanic activity, gns.cri.nz/volcano for volcanic hazards, and getthru.govt.nz for what to do before, during and after volcanic activity. Version 3.0, 2014.

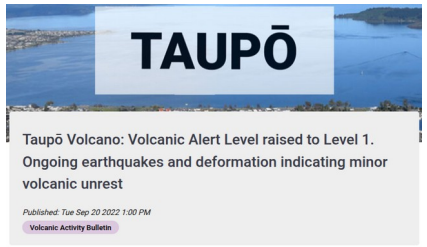
- Vote by Volcano Monitoring Group (selected members)
- Majority vote wins
- Tie decided by VMG chair
- Vote weekly, or as required
  - For VAL ≥ 1

Taupō VAL



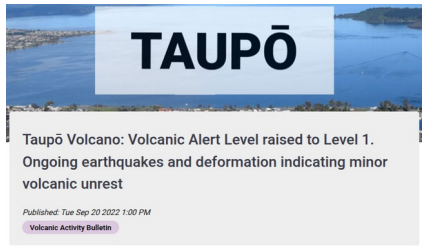
First vote May 30
VAL 0→1 Sep 19
VAL 1→0 May 30

Communications



13 x Volcanic Activity Bulletins (VAB) – major ‘official’ announcements, but also regular ‘updates’, produced by VMG

Communications



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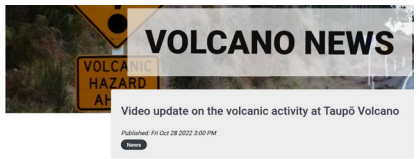
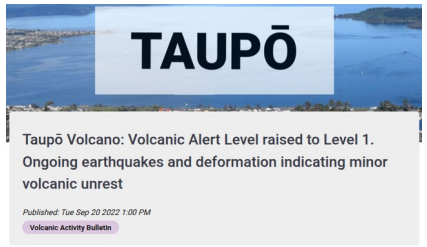


7 x News – less scientific, including video Q&A, produced by Comms team

Communications



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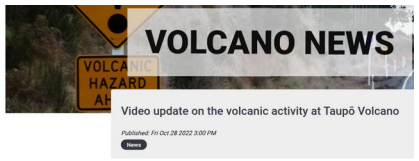


GNS Science Volcanic Fluid Geochemist Ery Hughes gives us an update on what's been happenin the Volcanic Alert Level was increased to Level 1 on 20 September 2022.

7 x News – less scientific, including video Q&A, produced by Comms team

Taupō Volcano Scenarios

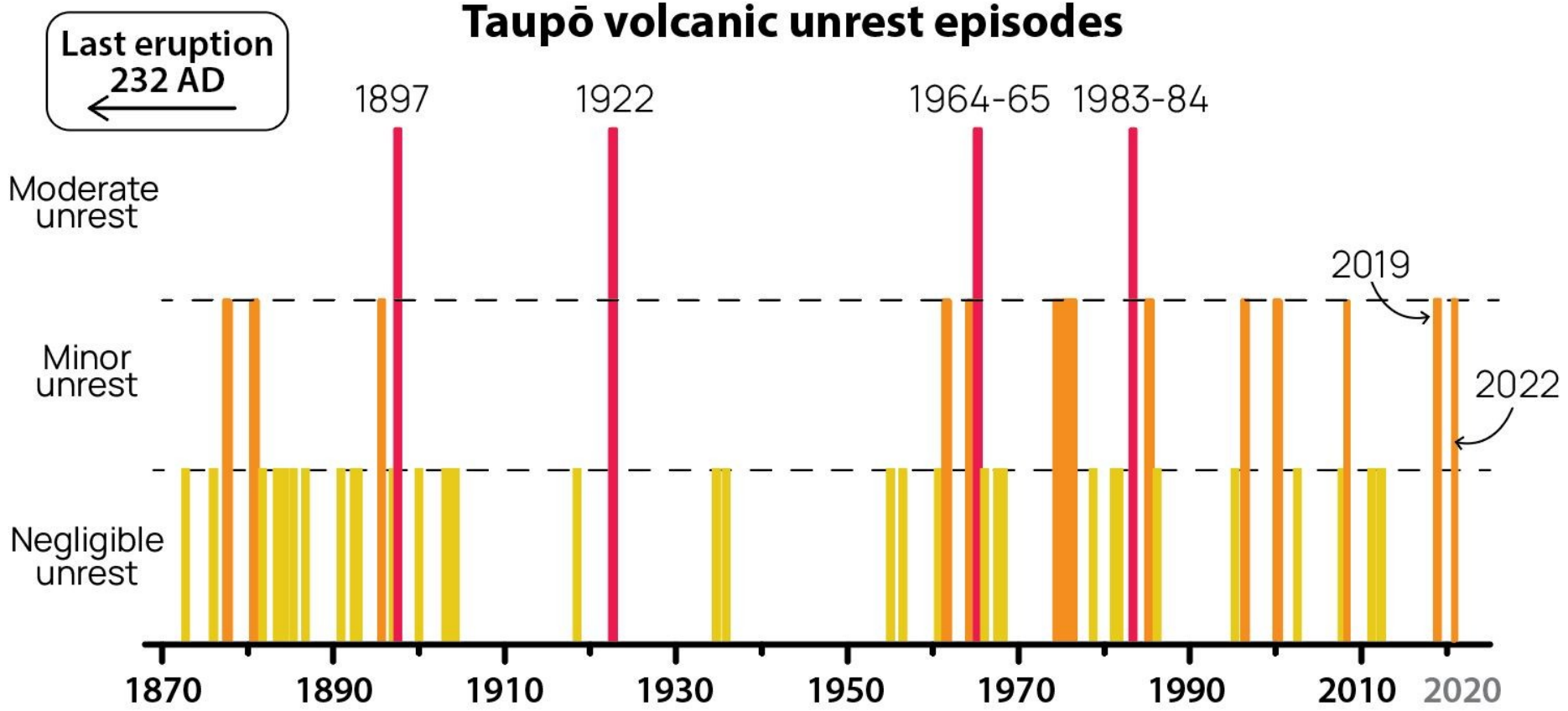
Version: 1.02
25 October 2022

Relative likelihood of scenarios occurring for Taupō volcano from its current state of minor unrest (VAL1) within the next three-month period (5 October 2022 – 5 January 2023)

	Scenario	Examples	Potential hazards	Likelihood of scenarios occurring within the next 3 months (at 2 s.d.)
A	***Minor unrest decreases to no unrest (VAL1→0)***	**2019 at Taupō** An elevated number of earthquakes continued for around 8 months in total, including a M5 damaging earthquake. Uplift occurred at a rate of about 10mm/year.	• Minor unrest hazards decrease and return to normal background levels.	0-53% Unlikely/About as likely as not
B	***Minor unrest continues (VAL1)***	**2008-2010 at Taupō** Up to 150 earthquakes recorded per day over nearly 2 years, four >M4.0. Inflation near Horomatangi Reef with uplift recorded of 40-50mm/year.	• Rate of earthquakes (number per week) remains similar to May - Sept 2022 • Earthquake shaking felt, potential for damage from stronger events (up to about M7), may trigger landslides and possible tsunami • Instrumentally detected ground deformation	17-97% Unlikely/Very likely
C	***Minor unrest increases to moderate or heightened unrest (VAL1→2)***	**1983-84 at Taupō** Uplift of 53mm in northern caldera area, rupture of Kaiapo Fault near Kinloch and subsidence of western side of the Fault. Earthquakes occurred for 13 months, causing minor structural and contents damage. This example is at the lower end of Scenario C.	• Notable increase in size and/or number of located earthquakes (up to about M7), may trigger landslides • Ground deformation may become visible and disrupt shallow underground infrastructure, particularly in the case of fault rupture • Hydrothermal system responses or explosions mostly underwater in Lake Taupō, such as a burst of hot water and steam above the vent(s), with potential tsunami – at the upper end of this scenario.	0-55% Unlikely/About as likely as not

Scenarios to local council and iwi, not publicly released

2022-23 considered minor unrest



To do, before next unrest

- Improve earthquake location capability
  - Velocity model
  - Stations in network hole – not possible within funding

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  - Stations in network hole – not possible within funding
- Bayesian unrest estimate – in progress

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- People were not too bothered about volcanic unrest, contrary to my expectations - despite the ‘supervolcano’ status
- Lack of concerns feels different from other examples
  - Campi Flegrei, Long Valley