Earth Sciences
New Zealand

YEAH, NAH

An introduction to

Geohazards Monitoring in Aotearoa New Zealand

Presented by

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Earth Sciences
New Zealand

What this presentation will cover

Earth Science New Zealand and GeoNet

The data we collect

Monitoring and Response in Aotearoa New Zealand

Who we are

On July 1, 2025, **NIWA** and **GNS Science** merged to become the new organisation called **Earth Sciences New Zealand (ESNZ).**

This merger:

- Combined GNS and NIWA under one name.
- A lot of work still to come to fully combine the two organisations.
- Will still deliver good science for public use, across both GNS and NIWA programmes and disciplines.

Purpose statement:

Driving economic growth and wellbeing through increasing returns from the use of New Zealand's natural resources and environments, enhancing energy security, building hazard resilience and increasing prosperity in a changing climate.

What is the GeoNet Programme

The GeoNet Programme is delivered by ESNZ as New Zealand's national land and geohazards data and monitoring system.

The programme is made up of:

- **A data pipeline**, physical and virtual infrastructure, systems, and practices that enable data collection, dissemination, and custodianship.
- **Monitoring and Response**, are dependent on the data pipeline.
- **Governance structure** representing all funding stakeholders and GNS, to advise on decisions and advocate for the programme at different levels.
- **He tāngata he tāngata he tāngata,** it's the people who ensure everything works – from the infrastructure to the data to the strategic management of the programme and facilitated delivery of objectives to monitoring and rapid response.

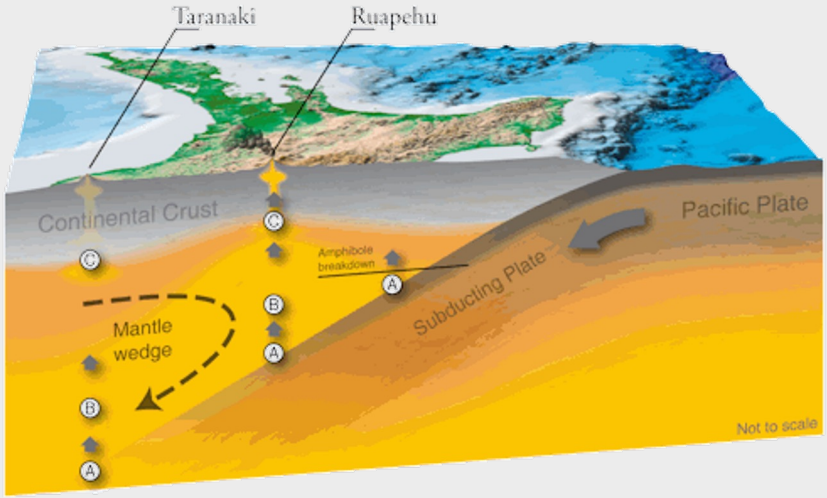
GeoNet creates impact with its partners.

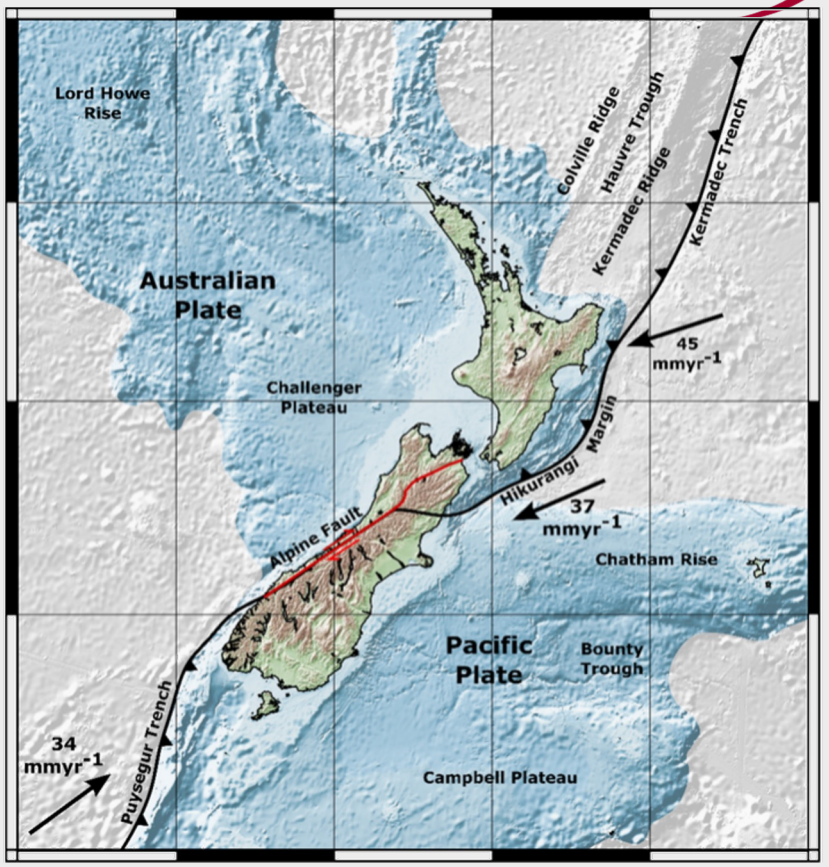
As a key part of the science advice value chain, GeoNet works closely with research & delivery and impact partners, such as those delivering other programmes, organisations, and agencies to build up collective knowledge and create impact in ways that help Aotearoa be safer and more resilient.

Why?

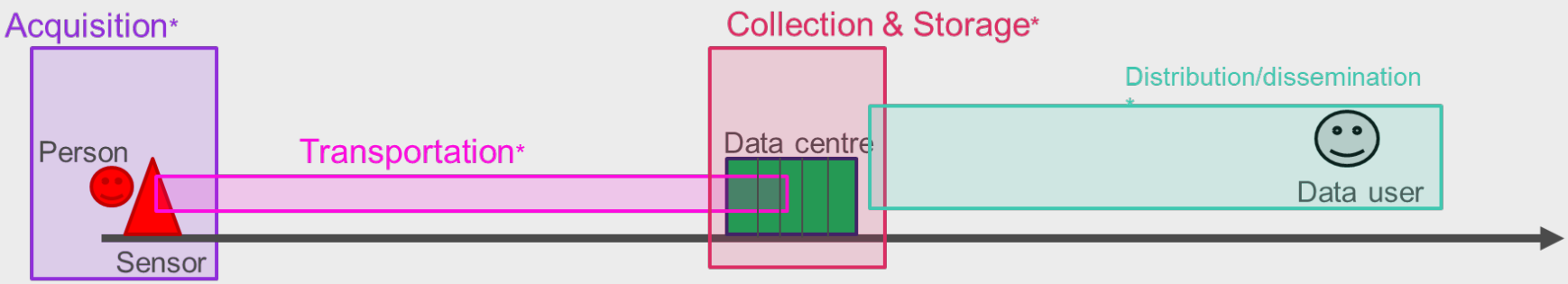
To help us build our collective understanding of Aotearoa's tectonic, earthquakes, landslides, tsunami, and volcanoes.

GeoNet was funded in 2001 to provide free and open data to enable research and monitoring into Te-Riu-a-Māui Zealandia and these hazards.





Everything depends on data



To maintain the data pipeline requires a huge range of skills and expertise, not just scientists!

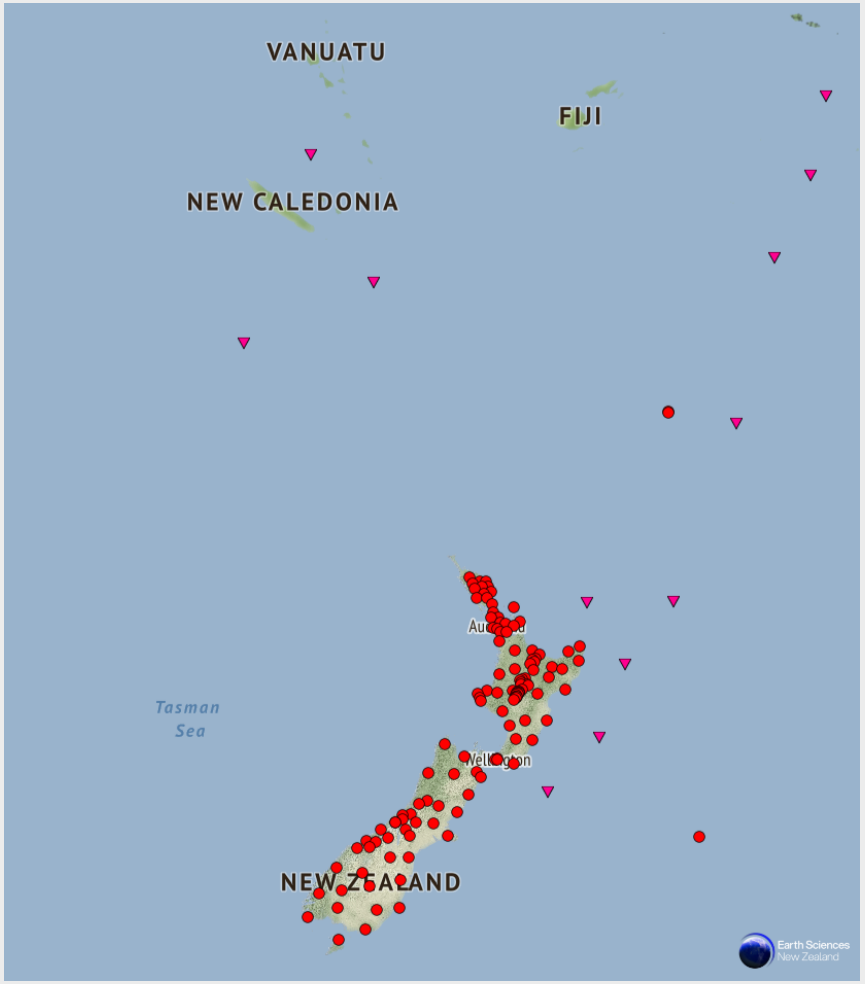
- Field techs: electricians, plumbers, builders, mechanics, asset managers, and more…
- Engineers: platform, cloud, software, network…
- Software developers & solutions architects
- Data custodians – people who know information management inside out, care for the data, make sure it's useful, usable, used….
- Specialists in user-centric design and user engagement
- Managers, project managers, product owners, finance, health & safety…

Where it all begins: GeoNet's Sensor Network

The network consists of over 1,000 sensors around mainland New Zealand, the islands, and the South Pacific.

Stations include:

- Broadband seismometers
- Short period seismometers
- Strong Motion accelerometers
- GNSS stations
- Volcano cameras
- Acoustic sensors (infrasound microphones)
- Tsunami gauges (coastal and lake)
- DART sensors (deep-ocean pressure gauges)

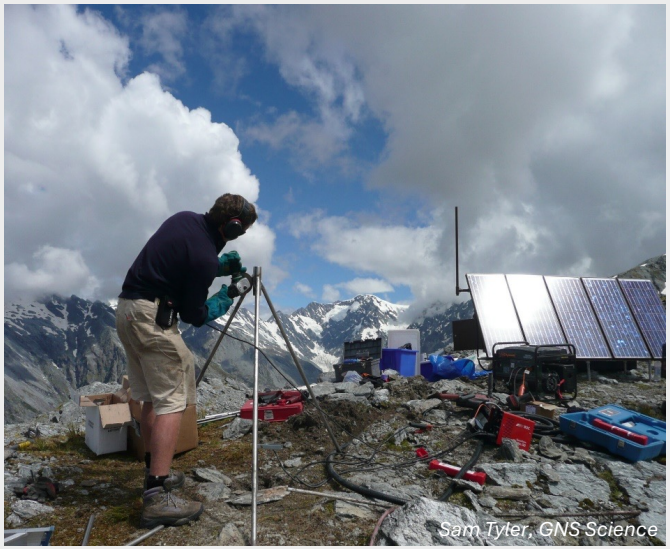


GeoNet's Sensor Network

Our stations and their data feeds are maintained by in-house teams with a variety of skills and backgrounds.

They handle the whole process from site selection to relationships with landowners, configuration, installation, and maintenance of the sensors through to ensuring that the data is available, accessible, and usable.

Great Barrier Island



Westland

Central Plateau

Lake Taupō

Seismic Data

The GeoNet network collects multiple types of data related to seismicity.

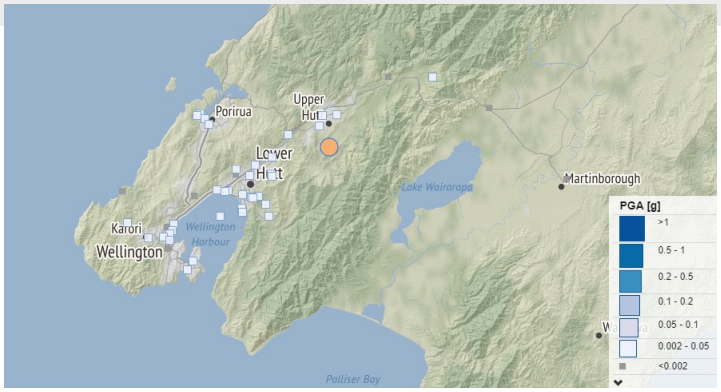
Seismometers:

- Digital force-balanced
- Multiple sensor types
  - Broadband seismometers.
  - Short period seismometers.
  - Strong motion accelerometers.
- Sampled at 100Hz
- Often pick up non-seismic signals

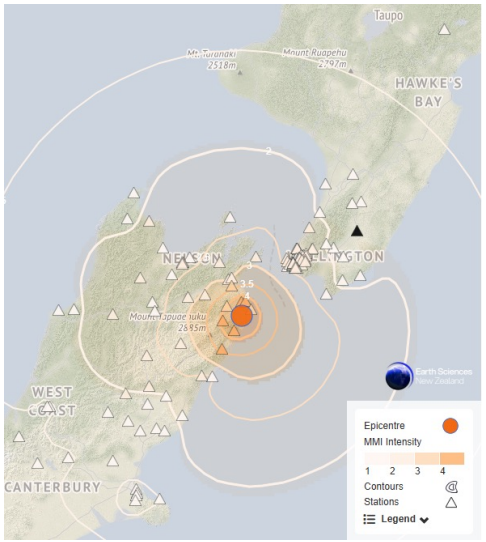
Geodetic data: Earth surface movement and slow-slip earthquakes are monitored by GNSS stations. These have a standard sample rate of 30s, but even higher rates can be retrieved.

These data are also input into GeoNet's bespoke tools:

- **Shaking Layers** estimates ground shaking intensity using community-derived felt reports and strong motion stations.
- The **Strong Motion tool** gives a quick estimate of the maximum PGA and PGV experienced at the station.



The *Strong Motion* produced by an earthquake near Wellington.



The *Shaking Layers* map produced by an earthquake in Seddon

Tsunami Data

Tsunami data takes two main forms at GeoNet:

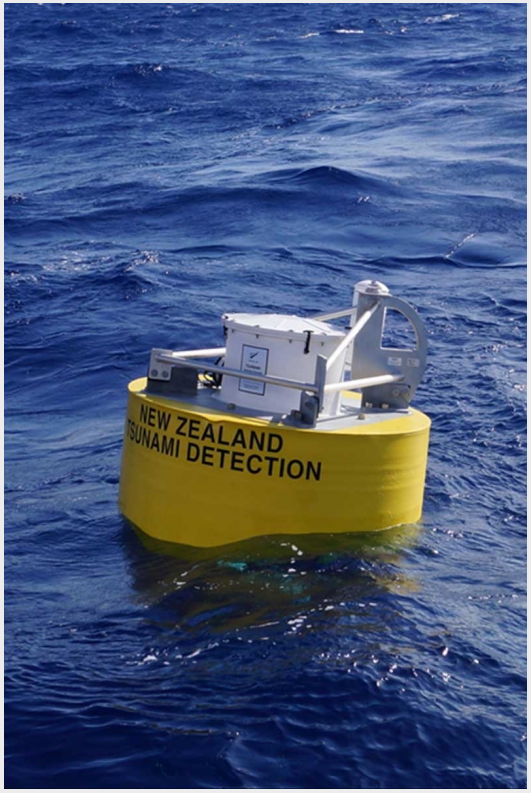
The **tsunami gauges** located at the coast (and in Lake Taupō) continuously monitor the water level.

- Pressure sensors calculate the water depth.
- One- and ten-samples per second, collated into 1-minute averages to lessen wave variability.
- Two sensors at each site for redundancy.

The 12 **DART Sensors** (Deep-ocean Assessment and Reporting of Tsunami) consist of a pressure recorder at the ocean floor, and a buoy at the surface to transmit the data via satellite.

- Packets of 15-minute standard tide data and buoy location data sent as "BAU".
- High-rate (15-second) data when a significant (≥30mm) change in water level is detected.
- Able to be manually 'triggered' to collect high-rate data as needed.
- Two parallel setups within the buoy system for redundancy.

The resulting data from both systems feed into international tsunami detection systems.

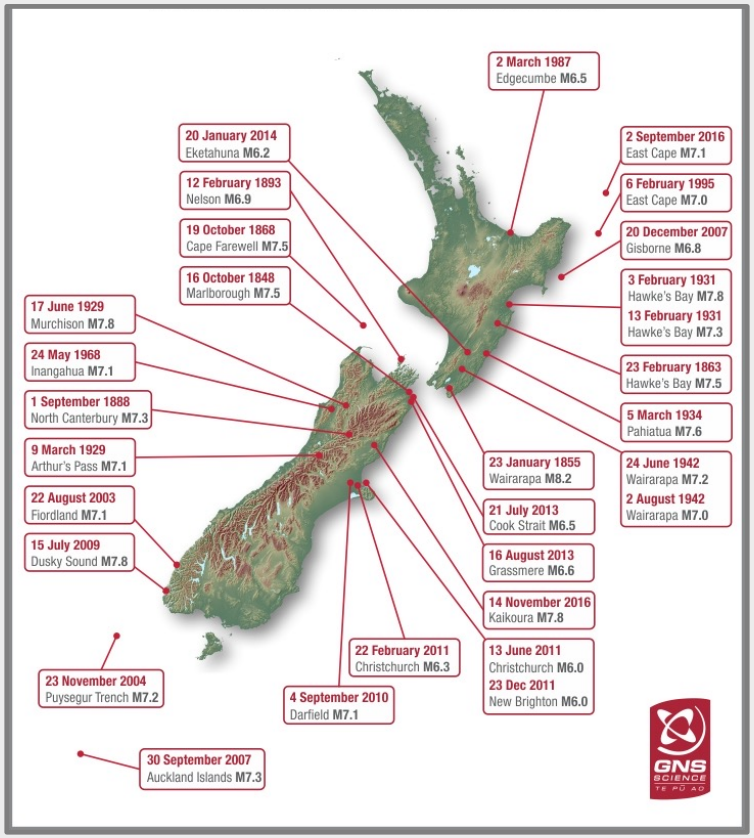


One of the buoys in the New Zealand DART network

Major events

REGIONAL AND DISTANT SOURCES

2009: Samoan Islands Tsunami
2010: Chile Tsunami
2011: Japan Tsunami
2015: Chile Tsunami
2021: Loyalty Islands earthquake (M7.7) + tsunami
2021: Alaska (M8.2)
2022: Hunga Tonga-Hunga Ha'apai eruption + tsunami
2023: Loyalty Islands earthquake (M7.7) + tsunami
2024: Vanuatu earthquake (M7.3)
2025: Kamchatka earthquake (M8.8) + tsunami



LOCAL EVENTS

2009: Dusky Sound (M7.8) + local tsunami
2010: Darfield (M7.1)
2011: Christchurch (M6.2)
2011: Canterbury (M6.0, M5.8, M5.9)
2012: Tongariro Eruptions
2013: Cook Strait (M6.5, 6.6)
2014: Eketāhuna (M6.2)
2015: Wilberforce (M6.2, M6.2 M5.8)
2016: Christchurch Valentines Day (M5.7)
2016: East Cape (M7.1) + local tsunami
2016: Kaikoura (M7.8) + local tsunami
2018: Taumaranui (M6.2)
2019: Whakaari eruption
2020: Kermadec earthquake (M7.3) + local tsunami
2021: March 5th "Trinami" day (M7.3, M7.4, M8.1) + local tsunami
2022: Ruapehu unrest
2022-3: Taupō unrest (incl. M5.7 + lake tsunami)
2023: Auckland Anniversary floods + Cyclone Gabrielle
2023: Porongahau (M5.9)
2023: Geraldine (M6.0)
2024-5: Whakaari unrest
2025: Puysegur earthquake (M6.8) + local tsunami

Earth Sciences New Zealand - Role in Emergency Response

Main role

To provide evidence-based advice to lead and support agencies across the 4 Rs.

Key interlocutors

NEMA
CDEM Groups
Scientific Technical Advisory Groups
Other agencies (e.g., Linz, EQC, FENZ, NZ police)

Hazard Detection, Monitoring and Response

- Maintain a state of readiness to respond.
- Manage GeoNet for detection of the 'four perils'.
- Assess tsunami threats with the Tsunami Experts Panel (TEP) and contribute experts to the Panel.
- Provide advice to NEMA on the issuing of warnings and advisories.
- Provide scientific advice to the National Crisis Management Centre (NCMC), agencies, and CDEM Groups as needed.
- Maintain weather forecasting and issue weather warnings.
- Issue volcanic ash advisories for aviation.

Public Information

- On Geological hazards.
- Marine geological, seafloor, and coastal hazards.
- Climatic and seasonal risks (e.g., drought).
- Weather-related emergencies.

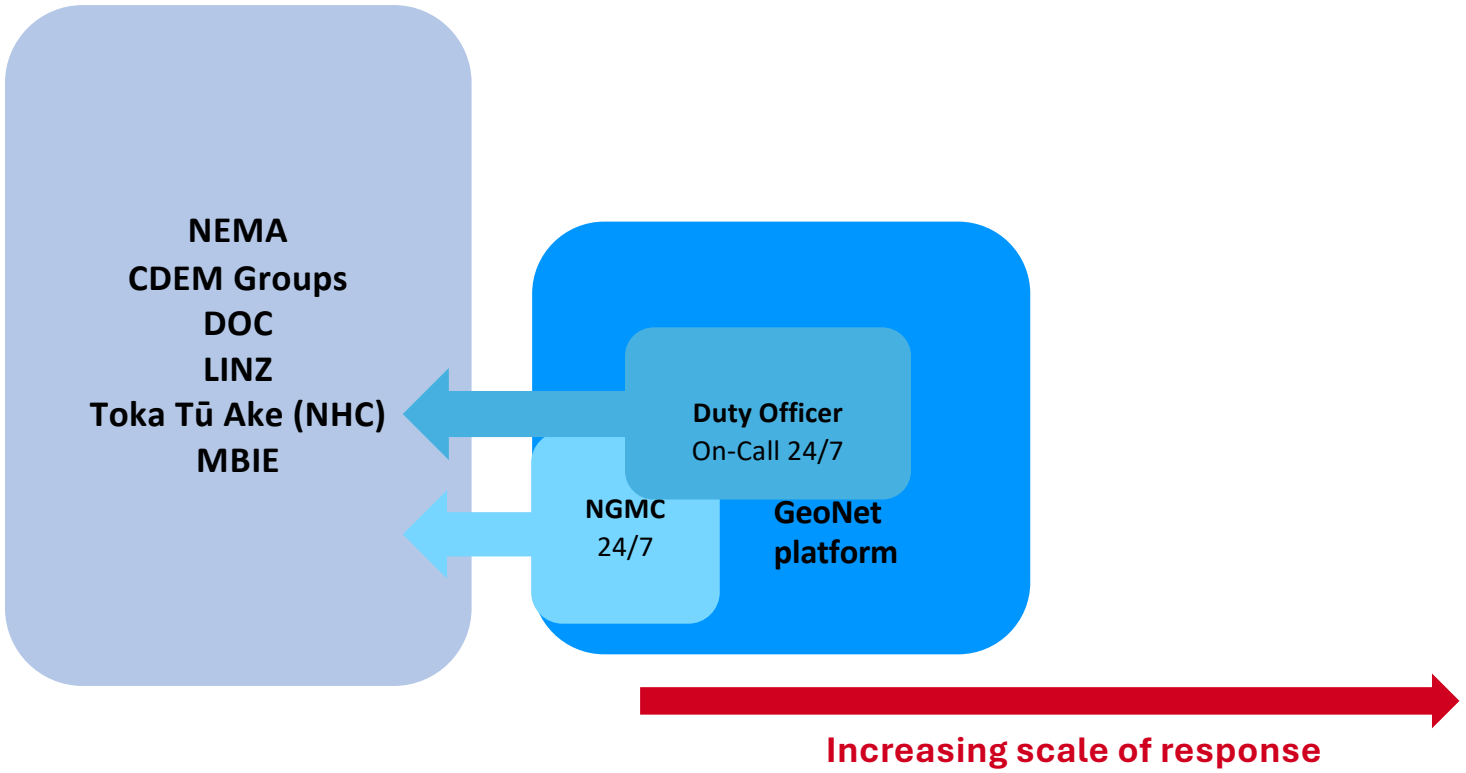
The Incident Management System (IMS)

The GNS business unit of ESNZ has its own **Incident Management System**, which is bespoke to Science needs and built upon the New Zealand Coordinated Incident Management System framework to enable sustained science advice with effective coordination between agencies.

Changes to standard CIMS reflect our depth across the science discipline and the mandate to respond both very rapidly and sustain science advice over a long period of time.
Our **IMS** ensures that the GNS Business Unit has the necessary people and skills, framework and tools to effectively and efficiently respond to a range of events.

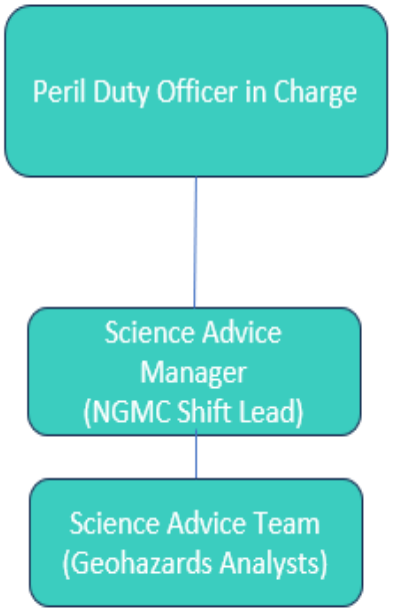
GNS Activation Levels

IMS Activation Level One



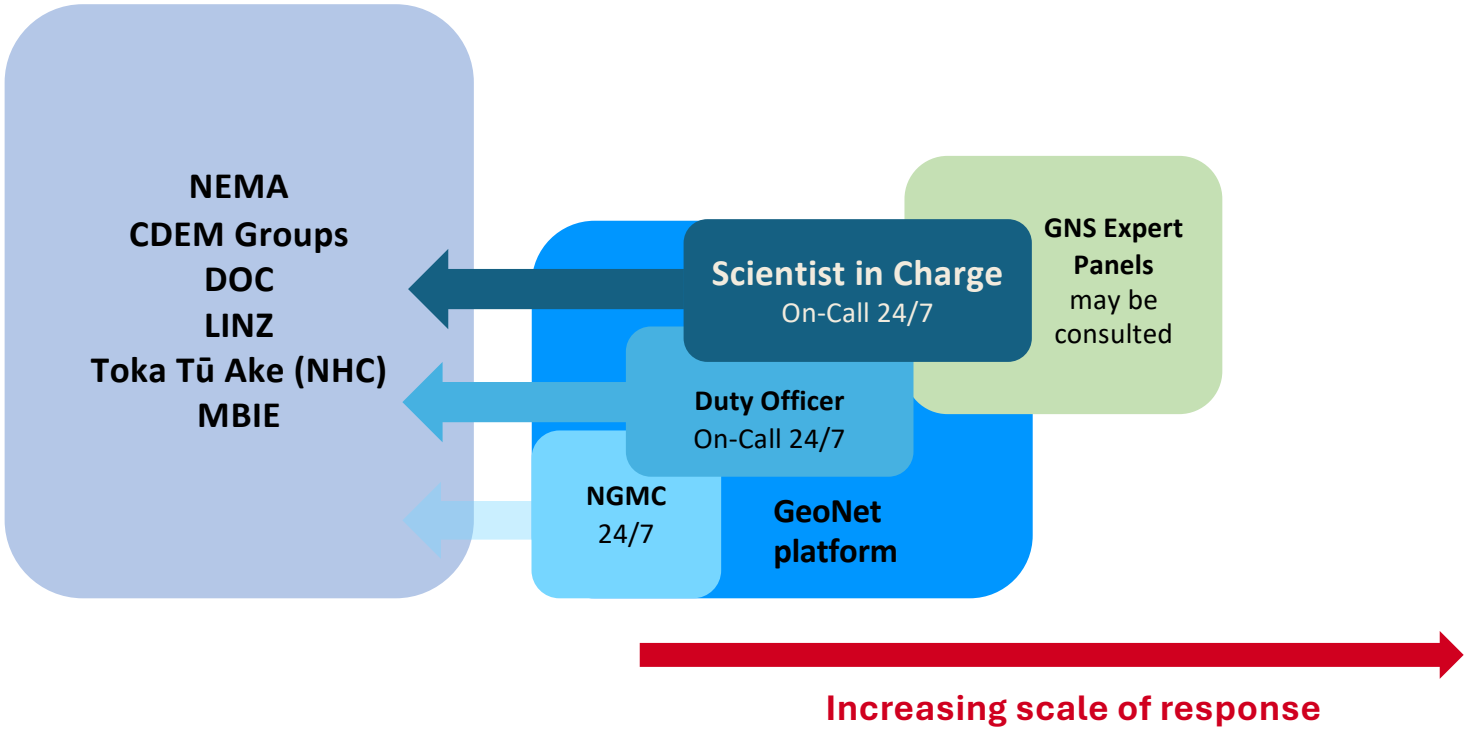
GNS Activation Levels

IMS Activation Level One



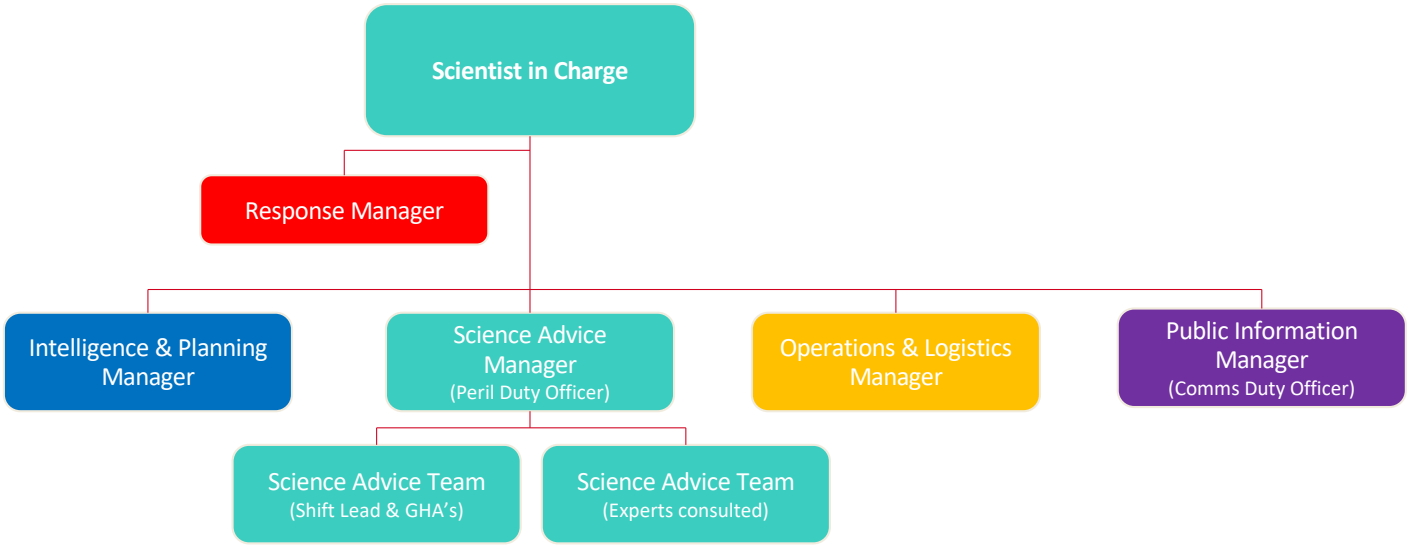
GNS Activation Levels

IMS Activation Level Two



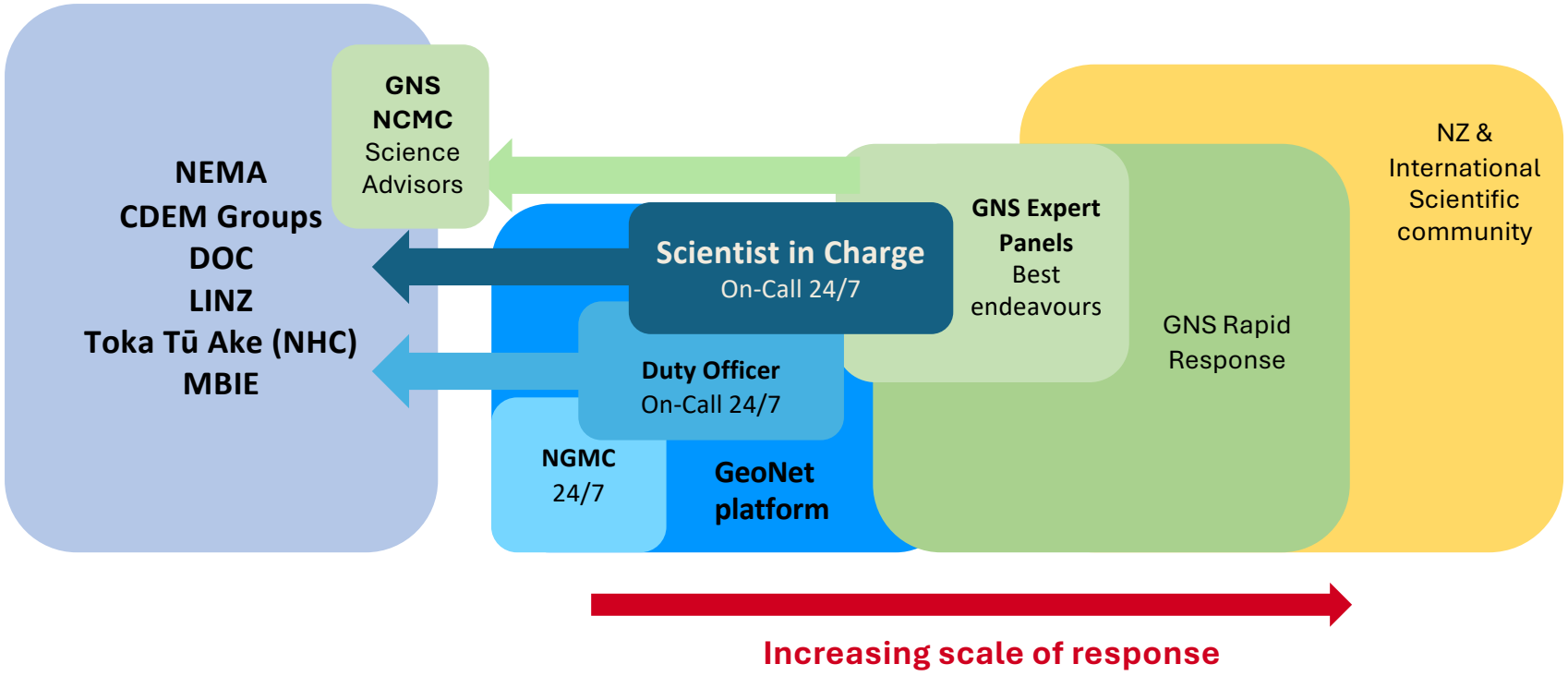
GNS Activation Levels

IMS Activation Level Two



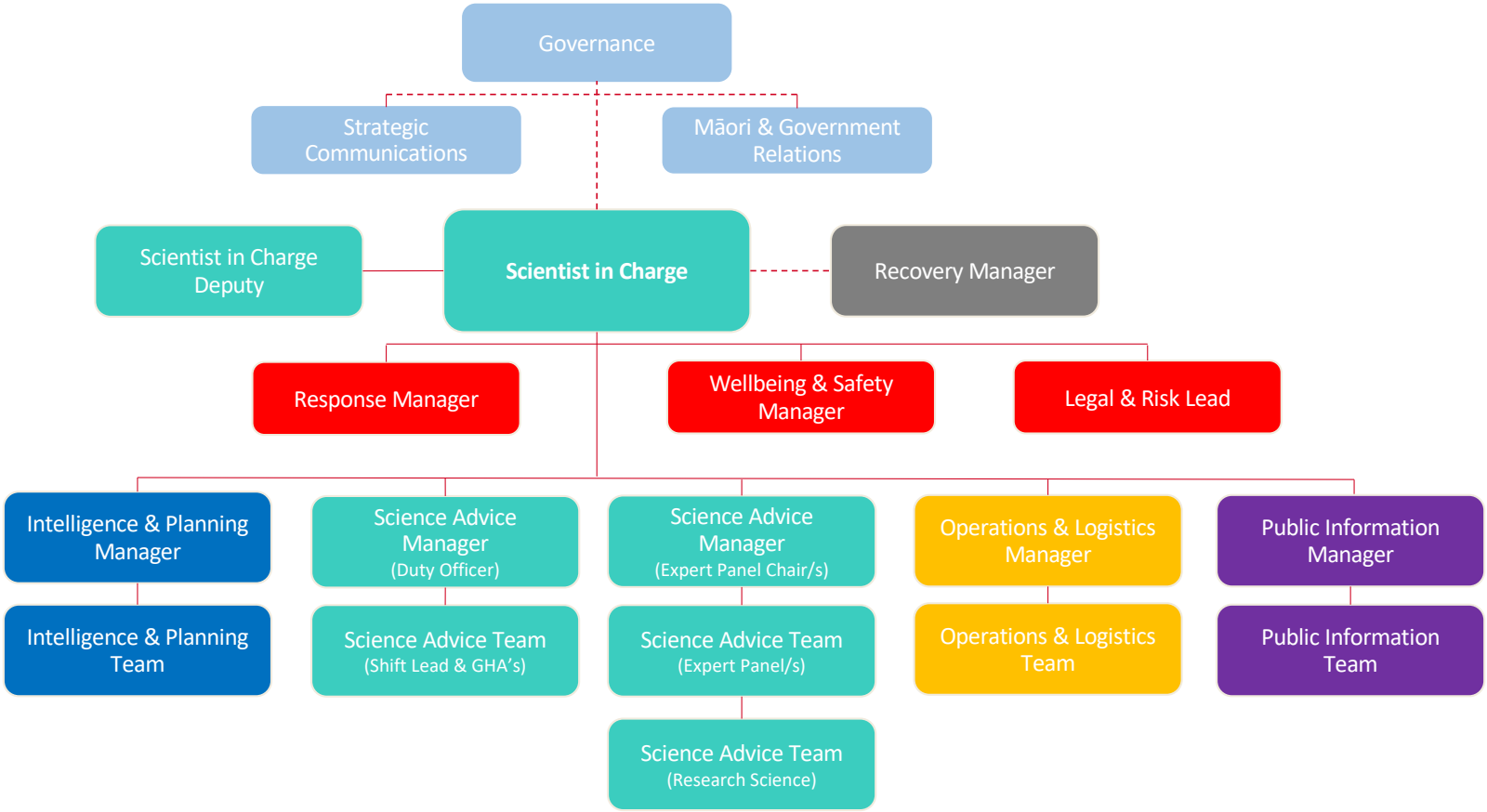
GNS Activation Levels

IMS Activation Level Three



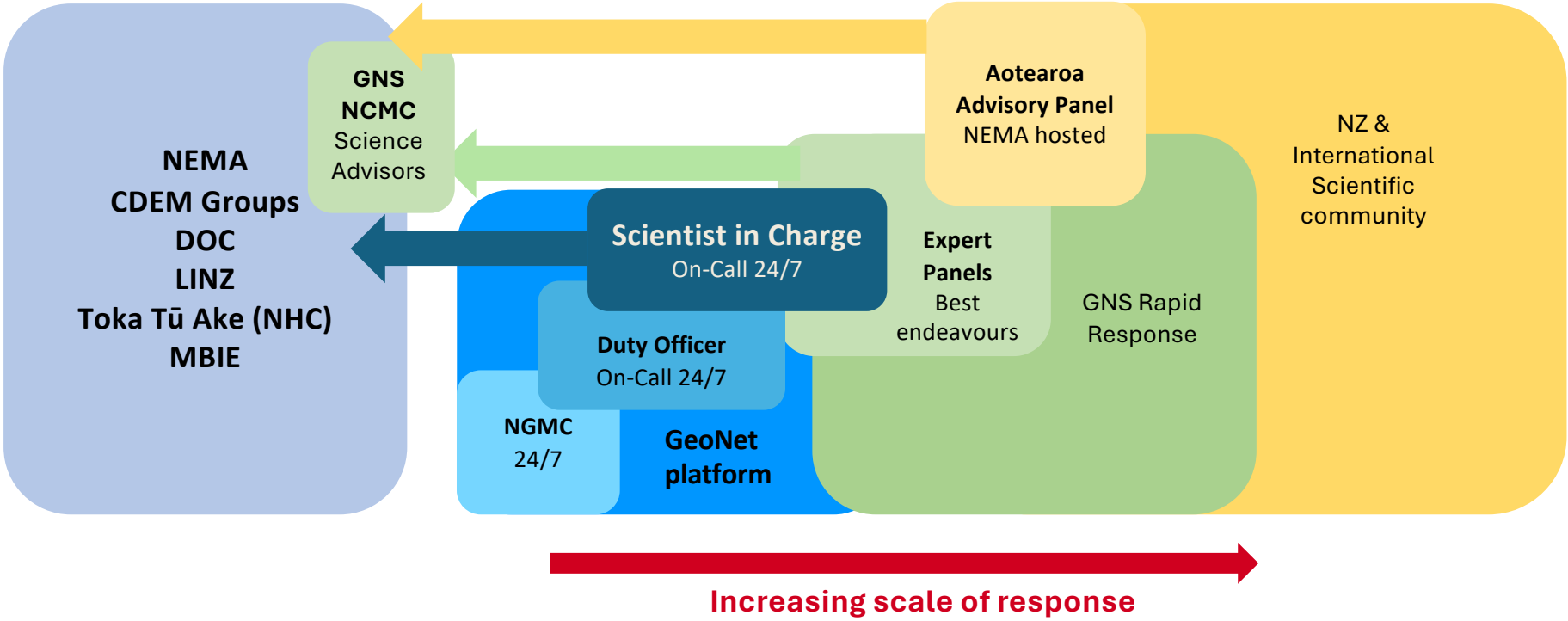
GNS Activation Levels

IMS Activation Level Three



GNS Activation Levels

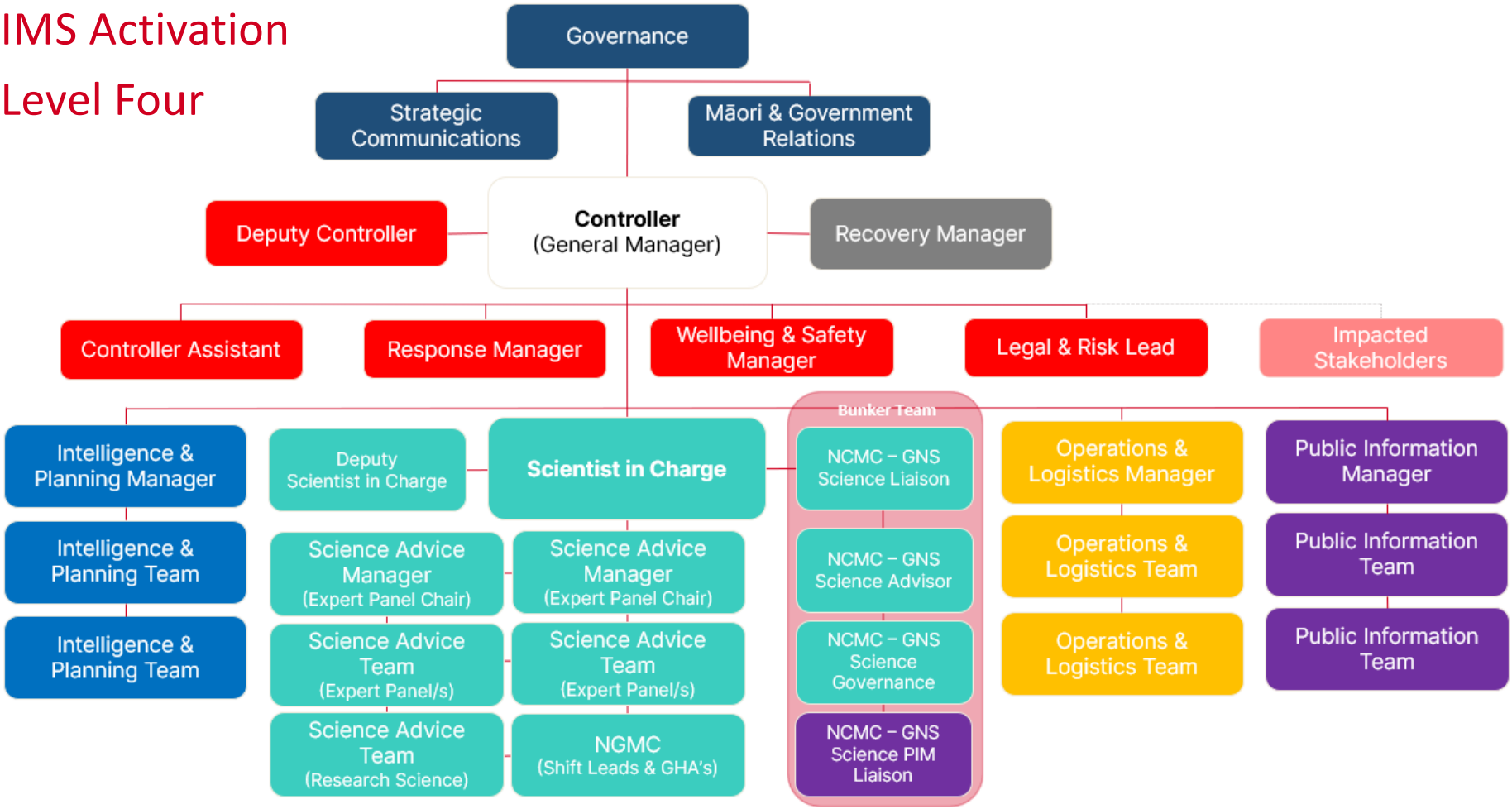
IMS Activation Level Four



GNS Activation Levels

IMS Activation

Level Four



National Geohazards Monitoring Centre

Established in 2018 as a GeoNet service through the Enhanced Geohazards Monitoring Project, initiated by government in response to the 2016 Kaikoura Earthquake.

24/7/365 eyes-on monitoring of earthquakes, landslides, tsunami, and volcanoes to ensure smooth escalation to events when they occur. The NGMC service supports delivery of rapid information and advice in response to geohazard events.

NGMC activities are an important part of many GeoNet services, particularly rapid ones, such as the refinement of earthquake parameters.

Staffed and operated primarily by staff in GNS' Monitoring and Response Team through their Shift teams of Geohazards Analysts.

The NGMC "Bridge" operations room during the March 5th Trinami Day response.

National Geohazards Monitoring Centre

Tsunami Expert Panel (TEP)

Tsunami warning in New Zealand

TEP — Establishment and Purpose

The Tsunami Experts Panel (TEP) was established in ~2009/2010 (or earlier?) and gained a more official role as required under the CDEM Order Section 85(2) – (b).

Under the National Civil Defence Management Plan Order 2015 (CDEM Order), the objective of science and research organizations is to provide evidence-based advice to support agencies and CDEM Groups across the 4Rs (Reduction, Readiness, Response, Recovery) in relation to risks to life and property from hazards.

Section 85 (2) of the CDEM Order describes the role of GNS Science during Readiness and Response:

(a) manages the GeoNet system for the detection of earthquakes, land movement, volcanic activity, and the potential for local-source tsunamis; and

(b) assesses the threat of tsunamis with the support of a multi-agency tsunami experts panel; and

(c) provides advice to the NEMA on the issuing of national advisories and warnings about geological hazards; and

(d) provides scientific advice to the NCMC, agencies, and CDEM Groups as needed; and

(e) contributes to the management of public information on geological hazards and associated emergencies.

The TEP is available 24/7 to assist with evaluations of tsunami threat to New Zealand in response to any events that could have tsunami potentials.

TEP — Structure, Roles and Responsibilities | Best Endeavours

- **Coordinator**
  - TEP administrations.
- **Chair (steady state/readiness)**
  - Organise/facilitate/chair steady state/readiness TEP meetings;
  - Point of contact for TEP members;
  - Representative of TEP in engagements with other groups and duty teams;
- **Members**
  - Invited from multiple agencies/institutes with expertise in relevant areas (e.g., seismology, tsunami, plate tectonics, historical events, etc.);
  - Participate TEP meetings, discussions and other activities as required (**readiness**);
  - Assist with developments and reviews of SOPs and guidelines (**readiness**);
  - When requested, provide trainings for the NGMC and Duty Teams and develop tsunami evaluation tools (**readiness**);
  - Participate **response** meetings, gather/assess information, and provide advice ("best endeavours").

Existing members: 10
- 8 from ESNZ
- 1 (Jose)
- 1 coordinator from ESNZ

Candidate members: 0

TEP Activations

Available 24/7

TEP members have often been self-activated by after receiving GeoNet/USGS/PTWC alerts through their own alert service subscriptions

Officially Activated by

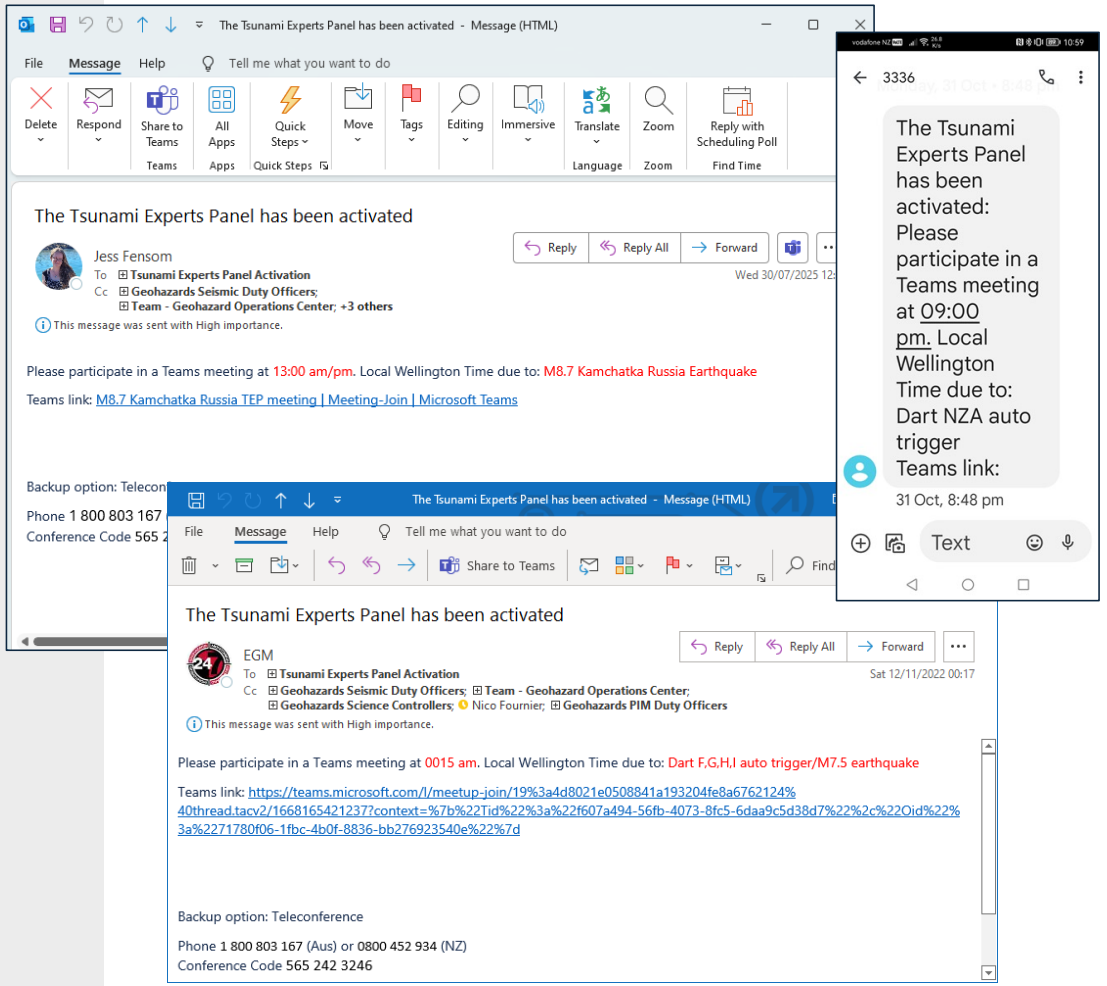
- Seismic Duty Officers (SDO)
- National Geohazards Monitoring Centre (NGMC) /Geohazards Analysts (GHAs)
- Geohazards Science Controllers/Scientists in Charge (SIC)
- …

often in 10 – 60 minutes after EQ

Activation alert sent via

- PagerDuty Alerts (GNS members)
- TXT/SMS
- Email
- Phone calls (teleconference sys.)

1st meeting in 5 – 30 minutes after activation

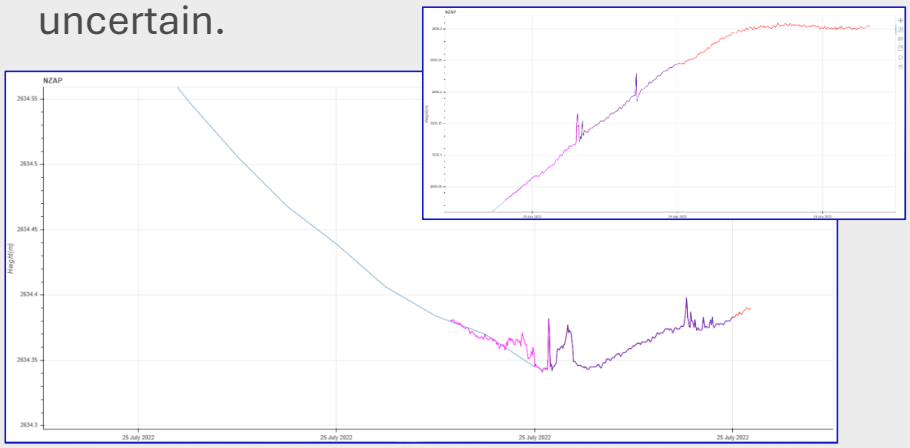


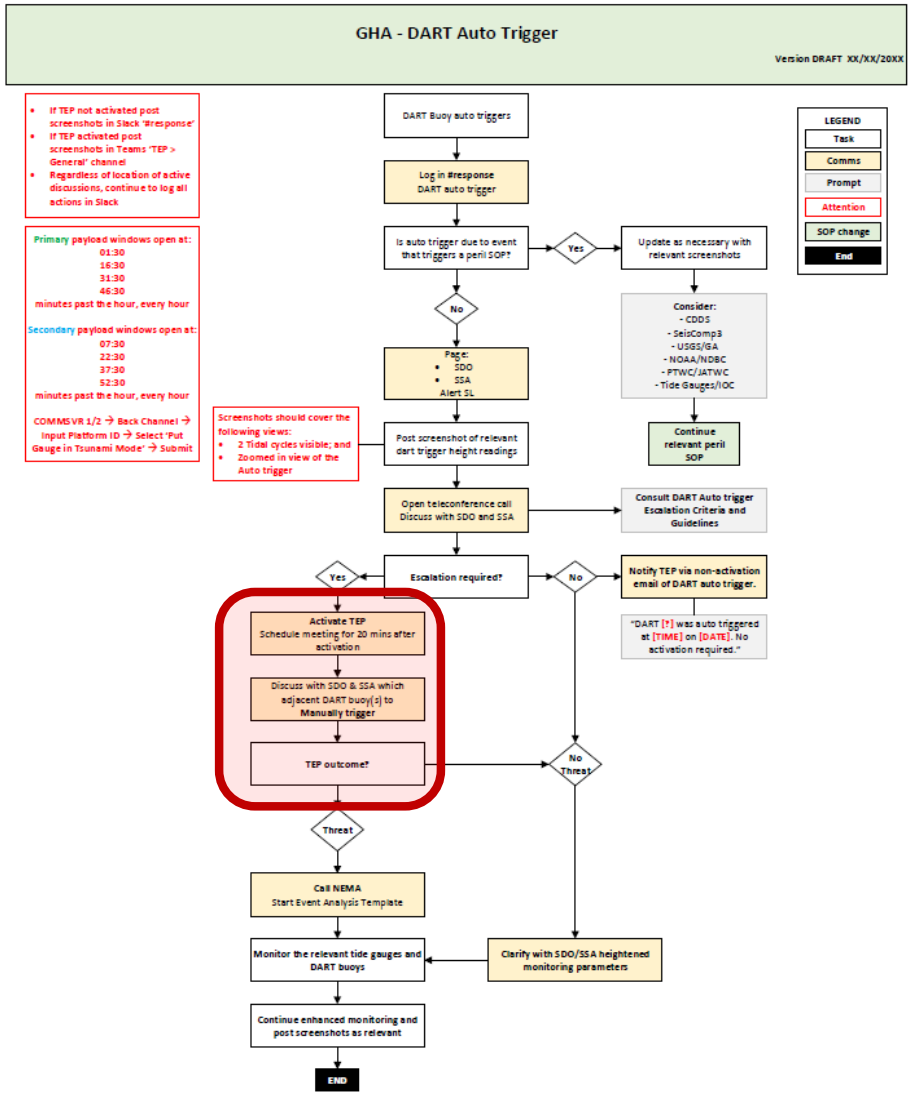
Multiple Escalation Points

TEP could be activated at anytime due to any event that would pose potential tsunami threat to NZ coast, e.g.

- Local, regional and distant earthquakes (magnitude threshold)
- DART Auto-triggers (water height threshold)
- Offshore volcanic activities
- …

or simply because of something unusual / uncertain.





How a TEP Response is Managed — Response Meeting(s)

TEP immediate response varies a lot depending on the nature and severity of an “event”, e.g., local, regional, distant event, DART autotrigger, etc. Immediate responses may last from around half an hour to a few days.

Response Meeting(s)

- One or a series of response meetings;
- Intervals between meetings vary from 30 minutes to a few hours;
- Time (and meeting chair if required) for next meeting decided at the end of current response meeting;

Meeting Chair

- SDO (or occasionally GHA) chairs TEP response meeting
- To brief event info., observations, what’s been done (e.g. any map/message sent to NEMA), any NEMA requests, timeframe for TEP advice, etc.;
- To facilitate TEP discussions, relay TEP requests to other parties, e.g., NGMC/GHAs, for further data/information;
- To appoint chair for next response meeting, if necessary;

Meeting Platform

- MS Teams (Teleconference plus email as backup system)

Meeting Participants

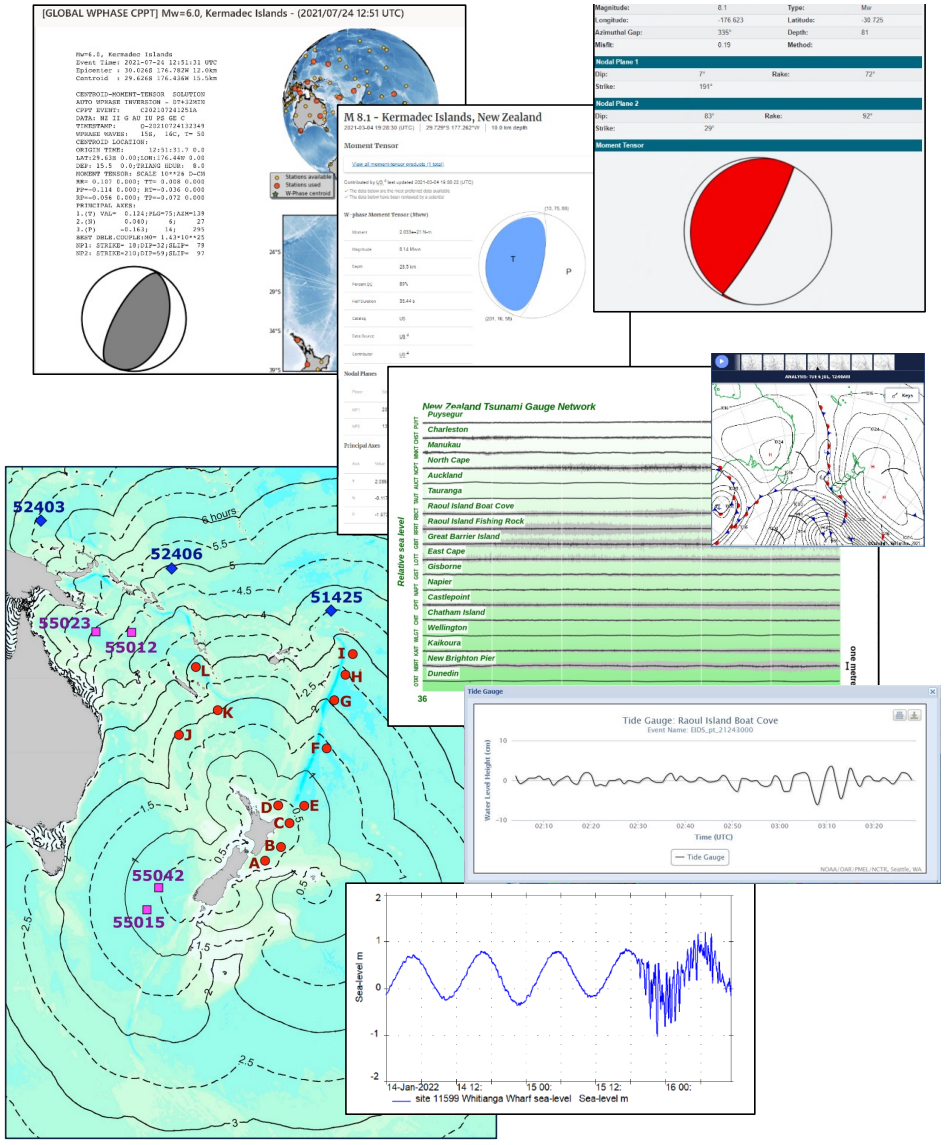
- TEP members + SDO + SIC + representatives from other duty/response teams, including: NGMC/GHAs, landslides, volcano, Earthquake Experts Panel (EEP), communications, IT, etc.

Meeting Outputs

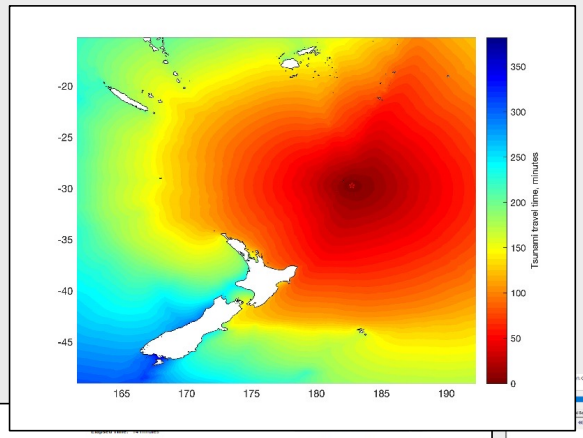
- Tsunami threat/action map (initial or updated), assessment/key message (to be sent to NEMA);
- If required, consistent message for Intelligence/Public Information.

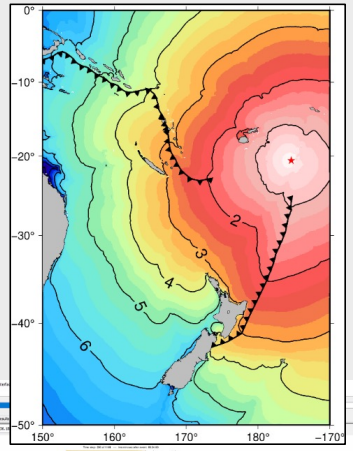
What We Do During Response

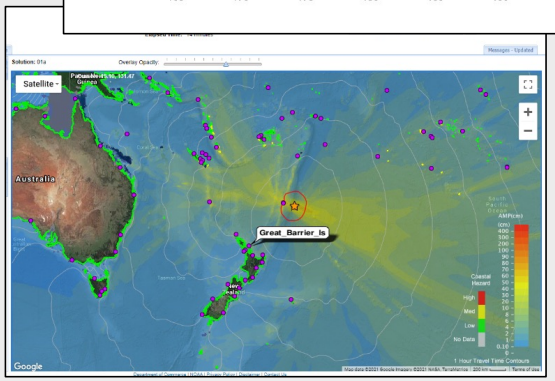
- Situation report by Meeting Chair;
- Review any map/message from NGMC;
- Digest and analyse any information passed by COM/GeoNet media team or other perils (e.g. earthquake, landslide, volcano;)
- Check & analyse source mechanisms/models, sea level gauge/DART observations, weather/sea conditions, historical records, local impact reports, GNSS observations, etc.;
- Assess tsunami travel times;
- Suggest any additional NZ DARTs activation;
- Discuss threat levels & Identify tsunami hotspots;
- Create/Update tsunami threat (Action) maps;
- Determine key message to NEMA;
- Determine time for next meeting and discuss what to do/task allocations (e.g. simulations) before next meeting;
- Determine heightened monitoring duration;
- discuss criteria for re-activation;
- Invert DART data for source when available, use ocean observations for modelling and forecasting impacts (key people).

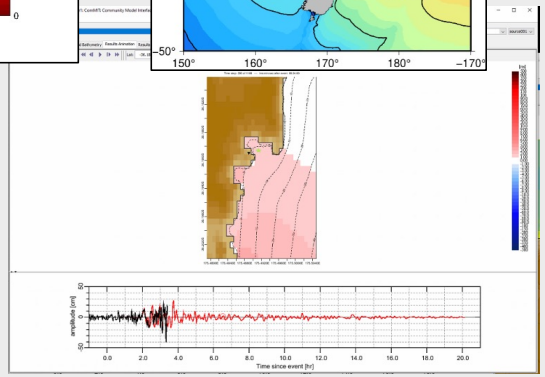


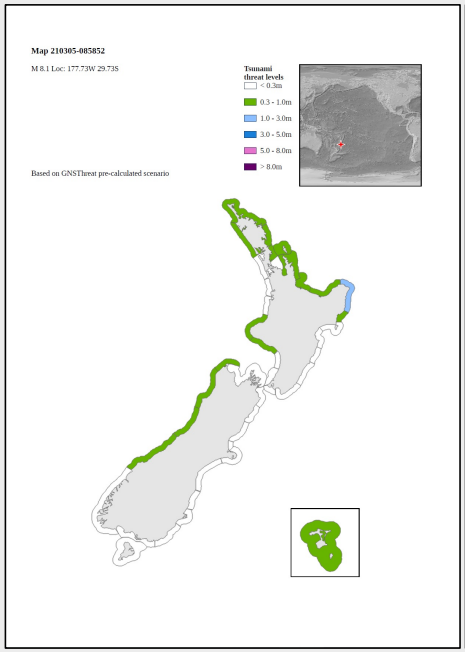
What We Do during Response — Example Outputs



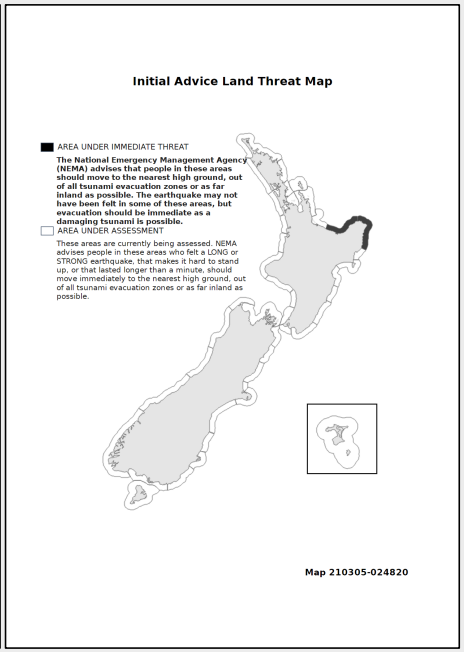








Example Threat Map

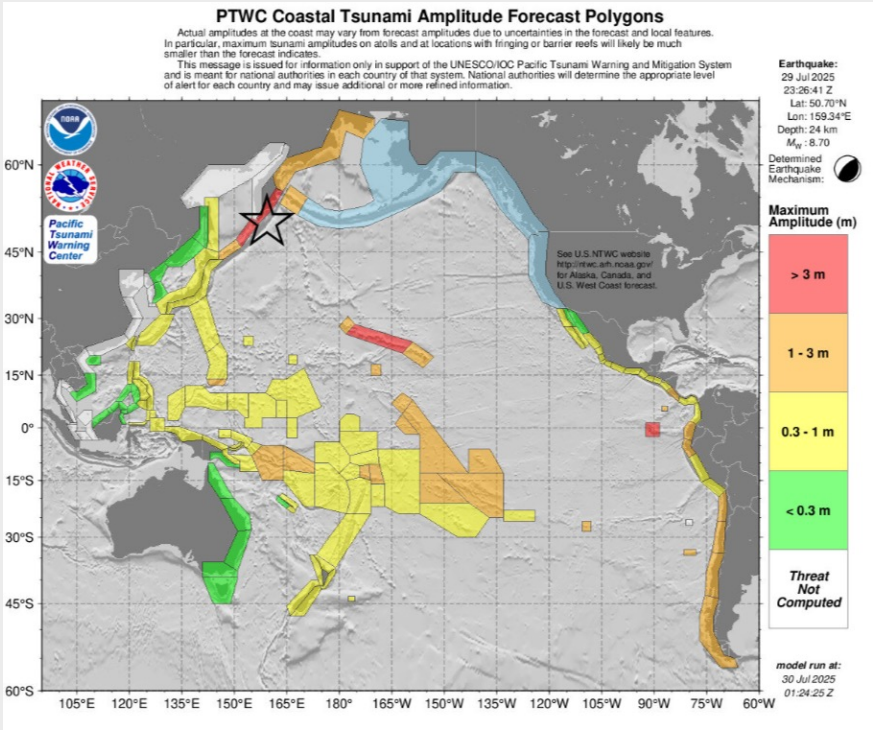


Example Action Map

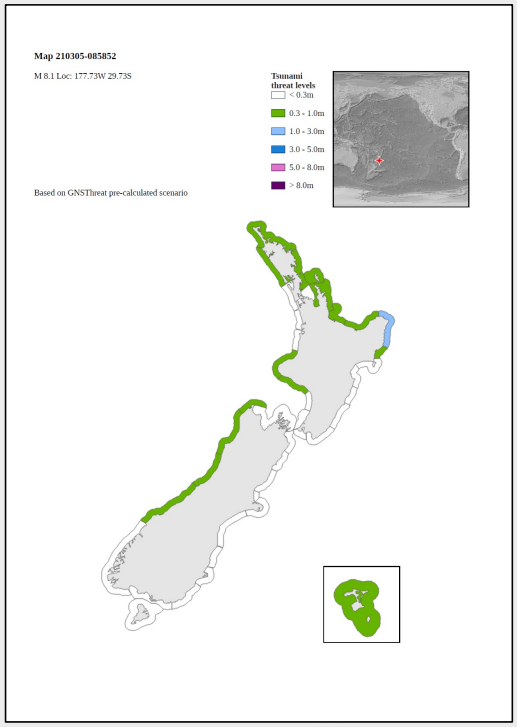
Example Message

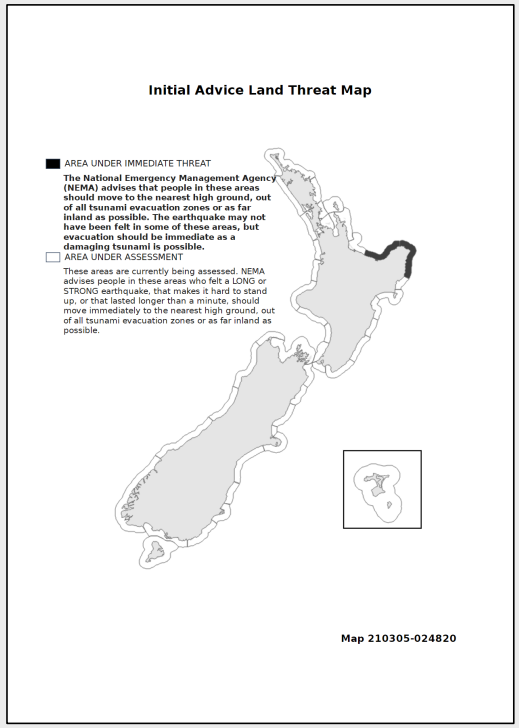
Based on modelling and ocean observations on tide gauges and the NZ DART array, we believe the beach and marine threat has passed for all parts of New Zealand including the Chatham Islands. In localized areas waves may continue to approach the beach and marine threshold of 30cm for several hours, but current science suggests these areas are unlikely to see waves significantly over 30cm.

PTWC


PTWC Coastal Tsunami Amplitude Forecast Polygons
Actual amplitudes at the coast may vary from forecast amplitudes due to uncertainties in the forecast and local features.
In particular, maximum tsunami amplitudes on atolls and at locations with fringing or barrier reefs will likely be much smaller than the forecast indicates.
This message is issued for information only in support of the UNESCO/IOC Pacific Tsunami Warning and Mitigation System and is meant for national authorities in each country of that system. National authorities will determine the appropriate level of alert for each country and may issue additional or more refined information.
Earthquake:
29 Jul 2025
23:26:41 Z
Lat: 50.70°N
Lon: 159.34°E
Depth: 24 km
M_W: 8.70
Determined Earthquake Mechanism:
Pacific Tsunami Warning Center
See U.S.NTWC website http://ntwc.arh.noaa.gov for Alaska, Canada, and U.S. West Coast forecast.
Maximum Amplitude (m)
> 3 m
1 - 3 m
0.3 - 1 m
< 0.3 m
Threat Not Computed
model run at:
30 Jul 2025
01:24.25 Z
60°N
45°N
30°N
15°N
0°
15°S
30°S
45°S
60°S
105°E 120°E 135°E 150°E 165°E 180° 165°W 150°W 135°W 120°W 105°W 90°W 75°W 60°W

TEP


Map 210305-085852
M 8.1 Loc: 177.73W 29.73S
Tsunami threat levels
< 0.3m
0.3 - 1.0m
1.0 - 3.0m
3.0 - 5.0m
5.0 - 8.0m
> 8.0m
Based on GNSThreat pre-calculated scenario


Initial Advice Land Threat Map
AREA UNDER IMMEDIATE THREAT
The National Emergency Management Agency (NEMA) advises that people in these areas should move to the nearest high ground, out of all tsunami evacuation zones or as far inland as possible. The earthquake may not have been felt in some of these areas, but evacuation should be immediate as a damaging tsunami is possible.
AREA UNDER ASSESSMENT
These areas are currently being assessed. NEMA advises people in these areas who felt a LONG or STRONG earthquake, that makes it hard to stand up, or that lasted longer than a minute, should move immediately to the nearest high ground, out of all tsunami evacuation zones or as far inland as possible.
Map 210305-024820

How a Response Ends — Often Gradual Without Clearcut

Heightened monitoring – stand by

- DARTs, coastal gauges, local impact reports, preliminary simulations, …;
- NGMC/SDO posts further observations to TEP Teams;
- TEP could be re-activated.

Tsunami threat passes – stand down

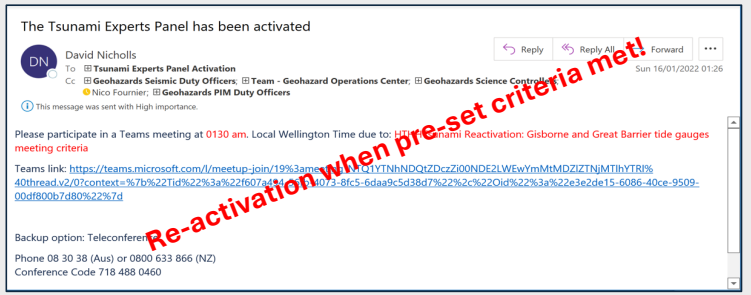
- "Official" completion of TEP response, back to BAU/Readiness.

Debriefs

- TEP debrief, NGMC debrief, GNS/NGMC-NEMA debrief.
- Lessons learnt: what went well, what didn't, how/what needed to do better next time (->further R&D).
- Actions to be followed up (can be challenging due to lack of resources/supports).

Transition to science responses

- Source mechanism investigations, field surveys, further modelling, collaborations (e.g. TsuRGe), publications.
- Media/public outreach.
- Research proposals, ……



Kamchatka Tsunami Response

Response is resourced and staff wellbeing is supported

Response progresses and delivers as planned across NGMC, TEP, SDO and SIC

Support any executive information and communication needs at ESNZ and partner agencies (primarily NEMA)

Partners supported in authoritative effective public information and warnings, primarily NEMA

Provision of timely, authoritative actionable science advice from National Geohazard Monitoring Centre (NGMC), Tsunami Expert Panel (TEP), Seismic Duty Officer (SDO) and Scientist in Charge (SIC) to support effective tsunami warnings and response by CDEM across New Zealand

Your questions

Ngā mihi nui!

Earth Sciences New Zealand™