DOI: https://doi.org/10.5592/CO/EUROENGEO.2024.208

DEVELOPMENT OF THE NEW ZEALAND LANDSLIDES DATABASE

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Abstract

There have been over 1,500 recorded landslide-related fatalities in New Zealand (more than from earthquakes and tsunami combined) since 1760. No single organisation in New Zealand has overall responsibility for landslides. As a result, landslide data has been stored in multiple discrete locations, often in widely varying formats, with no ability to compile the data to get an overall understanding of the distribution of landslide risk across the country. The New Zealand Landslides Database enables multiple organisations including the public to deposit factual information about every landslide into a single repository, and users to be able to access the data for their own purposes. Co-funded by the Earthquake Commission (EQC) and Auckland Council, with support from GNS Science, the beta version of the database went live in 2022. By sharing this data organisations gain significant benefits by understanding how landslides might affect their people and assets. This paper describes the development of the database and its use in a recent emergency event. It highlights the need for a consistent data schema to enable integration of multiple landslide inventories, describes the benefits, and proposes approaches to deliver the schema.

Key words

landslide, database, data, New Zealand

1 Introduction

Landslides are one of New Zealand's most significant natural hazards. Since 1760 there have been at least 1,500 deaths from landslides in New Zealand. More fatalities have occurred from landslides than from earthquakes (501), volcanic activity (179) and tsunami (1) combined over the last 160 years (de Vilder et al, 2024). A lower estimate of the national annual cost associated with landslides is NZ $250–$300 M/year (Rosser et al, 2017).

Before the losses from landslides can be reduced, the hazard must be recognised and the risk assessed appropriately. Risk, for the purposes of landslide risk management, is commonly defined as "*The potential for adverse consequences, loss, harm or detriment as a result of landsliding, as viewed from a human perspective within a stated period and area*." (Lee & Jones, 2023).

Risk is generally considered to be a function of the hazard (a landslide) and the consequences (in most cases, impact on people or property). A landslide susceptibility, hazard and/or risk analysis, commonly in the form of a map, provides a way to identify areas where landslides exist or could occur, what they may impact and therefore the risk that they pose (de Vilder et al, 2023).

Understanding the spatial and temporal distribution of previous landslides is required to inform susceptibility studies and risk assessment. A comprehensive landslide inventory provides this data. A landslide inventory is defined as "an inventory of the location, classification, volume, activity and date of occurrence of individual landslides in an area" (AGS, 2007). A landslide inventory is the most important information source for quantitative zoning of landslide susceptibility, hazard and risk (Van Den Eeckhaut & Hervás, 2012). However, no single organisation in New Zealand has overall responsibility for landslides, so data about the spatial and temporal distribution of landslides is fragmented and incomplete. This creates several challenges:

- It is challenging to undertake landslide susceptibility studies because the key input data, the landslide inventory, is incomplete.
- Members of the public struggle to identify who to report landslides to in emergencies. As a result, landslide reports are often directed to an inappropriate organisation, and by the time they get to the appropriate responders they lack key information like location and criticality.
- Homes and infrastructure are sometimes built in inappropriate locations because a history of land instability has been lost.

These challenges can be overcome by the creation of a robust and accessible landslide inventory. New Zealand already has several landslide databases, the most well-known of which is owned and operated by GNS Science, a government owned research institute. Although a valuable resource, GNS staff note some limitations that prevent it from being more widely used (pers. com.) including:

- It is only editable by GNS staff, meaning that utilities, territorial authorities and insurers are unable to add landslides they have identified.
- It is unfunded, meaning that GNS staff are unable to add many records.
- Quality assurance is not built in, meaning that some records are of questionable validity.
- User groups outside of GNS were not included in the database design, so it does not capture all the data they might need.

Because of these limitations, other databases have been developed. These include several landslide databases created by GNS and others for data relating to slow moving landslides, the Kaikoura earthquake triggered landslides and landslides in Wellington, the Bay of Plenty and others. There are also records of landslides held by the Natural Hazards Commission (NHC Toka Tū Ake, New Zealand's land insurance entity) in claims information, as well as many local authorities and infrastructure owners in a range of formats. This proliferation of data sources means that there is no way to produce a national map of landslides, and that compiling data is challenging due to the variable formats and standards used.

Without this consolidated, consistent and quality assured landslide inventory any efforts to assess spatial landslide hazard or risk will be flawed. Landslide hazard assessments are greatly enhanced if they include information on the magnitude, encompassing the distribution, type, density, size and impacts of landslides, and temporal frequency of past landslide events. The on-going capture of landslide records provides the magnitude and temporal frequency of landslide activity and its relationship with terrain types and individual triggering events, and this increases the reliability of landslide hazard assessment (Rosser et al., 2017).

2 Development of the New Zealand Landslides Database

2.1 Scoping

The NZ Landslides Database was developed to resolve the problems described above. The long-term goals for the Landslide Database are that it will, over time:

- Enable data to be standardised and consistent across all organisations that manage and use landslide information
- Replace legacy systems with improved and current technology and functionality
- Improve quality of landslide data
- Increase availability of landslide data to interested parties
- Improve public engagement relating to the reporting and viewing of landslide information
- Provide a source of landslide information for other related systems

- Become the national database for landslide data

2.2 Funding and development

Funding for the database development was obtained through the NHC Toka Tū Ake Biennial Grants programme, while hosting and staff time was funded by Auckland Council. Beca was engaged to refine the scope and develop the online tool. Development was undertaken in a series of ten two-week sprints, with testing and improvements happening in parallel. Ongoing improvements are underway in response to user needs, currently funded by Auckland Council.

2.3 Fundamental Principles

The database was built based on the following key principles defined by the steering group:

2.3.1 Unique identifiers

Each landslide has a unique identifier automatically assigned to it which never changes, allowing easy referencing. A URL for each landslide allows it to be linked from other sources.

2.3.2 One source of the truth

Landslide data can be easily entered in a single location by all the relevant organisations. An API (Application Programming Interface) is available to allow one-way information transfer from the NZ Landslides Database into other organisations internal systems in real time. This presents spatial information about each landslide which can be overlain on internal datasets such as asset locations or claims information without those commercially sensitive data being shared externally. Each landslide has a unique identifier (which is automatically assigned to each landslide by the database) that never changes. The Landslide ID can be used within organisations to link the landslide to internal information.

2.3.3 Internationally recognised data schema

To maximise compatibility with other datasets, data entry is limited to drop-down options aligned with the Hungr et al (2014) update to the Varnes classification scheme and the IAEG Commission 37 working group (Corominas et al, 2023).

2.3.4 Factual, non-confidential information

As the database is an open, shared resource, it would not be appropriate to hold private or confidential information. Instead, each record holds only factual information about the landslide and provides a unique identifier which can be referenced within organisations internal private systems. Private, commercially sensitive or organisation-specific information is held on those internal systems which reference the landslide unique identifier from the NZ Landslides Database.

2.3.5 Allow for increasing knowledge

When a landslide is first identified, it is often the case that relatively little is known about it. The database was structured to allow minimal information to be entered at first, and for additional information to be added over time.

2.3.6 Track change over time

Many landslides evolve over time. Some will re-activate and change shape or size. Others may be altered by human interventions (e.g. stabilisation works). The database was designed to record these changes without losing the history of the landslide. A time-slider allows change over time to be reviewed. This includes spatial mapping, which can be edited and added to over time, and these changes will all be tracked (Fig 4).

2.3.7 Allow landslides to be grouped (parent features)

As new information is collected, or as landslides evolve, it is common to identify that two previously mapped landslides are part of a larger feature. To manage this, each landslide can have a parent. This parent-child relationship allows small landslides to be linked to a record representing the larger feature. These links can be added at any time as new information becomes available. One parent record can have many child records, but each child can have only one parent.

2.3.8 Track all edits

To help ensure quality data, every change made to the database is recorded in a change log alongside the name of the user who made the edits (Figure 3). The history tracking described above allows a clear, documented trail of all changes (change log), records who made each change and the reason for the change (e.g. the change may be that new information became available, or the landslide reactivated and physically changed, or to correct an older error in the data).

2.3.9 Open to qualified users

Data can be added by any suitably qualified person, regardless of their organisation, once they have been approved as having the appropriate skills and experience. This allows a 'crowd- sourcing' approach to gain the maximum amount of data without compromising quality.

In general the level of knowledge and skill needed is that of an Engineering New Zealand Professional Engineering Geologist (PEngGeol) or equivalent. Users are expected to have a robust understanding of landslide classification schema, and to understand the importance of reliable quality data management.

2.3.10 No duplication

Where related (but not landslide specific) data is already held in other locations, it is not duplicated in the NZ Landslides Database. For example, borehole data already has a host in the NZ Geotechnical Database. The NZ Landslides Database instead references this data held elsewhere.

2.3.11 Allow for remediation

A common problem in urban areas is experienced when a landslide is partially or fully remediated. Landowners, worried about the stigma of having a landslide record on their property, often request that database entries relating to the landslide be deleted as they may mislead future purchasers. Allowing remedial works to be recorded enables the landslide record to be maintained while still satisfying the needs of the landowner.

2.3.12 Allow for public reporting

An unusual element of the database was the inclusion of a public reporting tool. This tool, presented as a simple online form, allows any individual to start a landslide record in the database. A screenshot of the public reporting tool is shown in Figure 1. Previously reported landslides are shown in the interface so that users can identify if the landslide has already been reported.

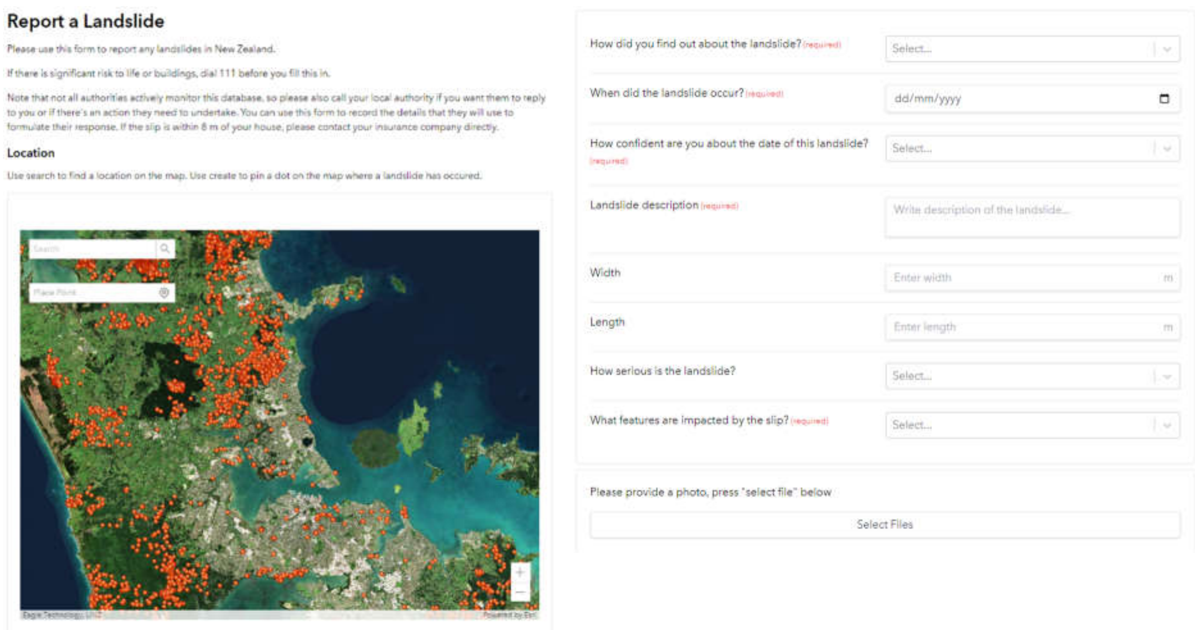

Figure 1. The public reporting tool showing existing reported landslides in Auckland.

This enables any individual to create a basic landslide record, represented as a single point on a map, with key data associated with it. The record can then be expanded upon by suitably qualified users once the landslide is investigated further, or it can be marked as invalid if there are errors or inconsistencies in the record.

Once submitted, the record is summarised as a simple PDF report (with personally identifiable information removed) and automatically forwarded on to a pre-determined list of email addresses. These can be set spatially, enabling asset owners (e.g. roading authorities) to be notified of landslide reports on their network without being overwhelmed with notifications from outside their area of interest.

2.4 Database structure

The core data about each landslide is stored in the master data table, which creates one source of truth for the landslide.

Table 1. Landslide data which can be assigned to master landslide record

Data Group	Data fields	Format
0. Public submission	0.1 Reported by (email)	email
	0.2 Reported by (Name)	Text
1. Identifiers	1.1 Parent landslide	Choice
	1.2 Landslide name	Text
2. Location	2.1 Location description	Text
	2.2 Location recording method or device	Text
	2.3 Estimated error in location recording method	Choice
	2.4 X Coordinate (NZTM)	Number
	2.5 Y Coordinate (NZTM)	Number
3. Description and setting	3.1 Physical setting	Choice
	3.2 Geological Setting	Text
	3.3 Geomorphological Setting	Text
	3.4 Landslide Description	Text
	3.5 Up-Slope Catchment Description	Text
4. Movement	4.1 Primary movement type	Choice
	4.2 Primary movement type subclass	Choice
	4.3 Secondary movement type(s)	Choice
	4.4 Complexity of mass movement	Choice
5. Date and activity	5.1 Has the landslide been active in the last 1000 years?	Choice
	5.2 Landslide activity	Choice
	5.3 Velocity class / rate of movement	Choice
	5.4 Estimated date of first movement	Date/time
	5.5 Accuracy of dating method of first movement	Choice
	5.6 Accuracy of dating method of most recent movement	Choice
	5.7 Estimated date of most recent movement	Date/time
6. Shape and dimensions	6.1 Slope angle prior to landslide	Number
	6.2 Slope angle of displaced material	Number
	6.3 Angle of rupture surface (translational)	Number
	6.4 Aspect (direction of movement)	Choice
	6.5 Length along ground zone of depletion	Number
	6.6 Length along ground zone of accumulation	Number
	6.7 Maximum height of main scarp	Number
	6.8 Maximum width of landslide perpendicular to direction of movement	Number
	6.9 Maximum depth from original surface to surface of rupture	Number
	6.10 Travel angle	Number
	6.11 Estimate of landslide area (min)	Number
	6.12 Estimate of landslide area (max)	Number
	6.13 Estimate of landslide volume (min)	Number
	6.14 Estimate of landslide volume (max)	Number
	6.15 Volume/area estimation method	Text
7. Materials	7.1 Materials in landslide	Choice
	7.2 Debris type	Choice

Data Group	Data fields	Format
	7.3 Vegetation cover	Choice
8. Triggers	8.1 Primary causal triggering factor	Choice
	8.2 Other factors influencing instability	Multi-choice
	8.3 Estimated magnitude of earthquake causing landslide	Number
	8.4 Rainfall Description	Number
	8.5 Rainfall total in preceding 24 hours	Number
	8.6 Rainfall total in preceding 3 days	Number
	8.7 Rainfall total in preceding 7 days	Number
9. Consequences	9.1 Damage description	Text
	9.2 Approximate number of injured people	Number
	9.3 Approximate number of fatalities	Number
	9.4 Approximate damage cost (NZ$)	Number
	9.5 Environmental damage	Text
	9.6 Features and assets impacted by the landslide	Multi-choice
10. Legacy data links		
11. Information sources	11.1 Source of landslide information (description)	Text
	11.2 Bibliographic reference of landslide information source	Text
	11.3 Project name / number	Text
	11.4 Original database (for bulk uploaded files)	Text
12. Quality assurance	12.3 QA Person Name	Text
	12.4 QA Person email	Email
	12.5 QA level	Choice
	12.6 QA status	Choice
	12.7 Comments	Text

Further details of the structure are presented in the database manual, available online (LandslidesNZ website), including guidance on content details which are also shows as pop-up tool tips in the database. A careful balance was struck between allowing a large range of data to be recorded, and relatively simple functionality which requires fewer fields. No fields are mandatory other than a unique ID and information about when the record was created, and by who. This enables a landslide to be created when little is known about it, and for data to be added as it becomes available. This overcomes a major shortcoming of some other databases that a landslide can only be recorded once it has been investigated in detail. Further information can be added at any stage by suitably qualified registered users.

In addition to the core metadata, an unlimited number of spatial features can be assigned to each landslide. These are entered graphically and are summarised in Table 2.

Table 2. Geospatial features which can be attached to the basic landslide record. Detailed definitions of each feature type are provided in the online manual to ensure consistent use.

Feature class	Types	Typical content
Landslide features	Points, Lines, Polygons	Landslide area, zone of depletion, zone of accumulation, hummocky ground, sinkholes, springs, scarp lines, cracks, damaged structures, breaks of slope, streams, landslide dammed lakes, etc.
Corrective features	Points, Lines, Polygons	Drains, retaining walls, anchors etc.
Photographs	Points	Images
Investigations & monitoring	Points	Links to NZ Geotechnical Database boreholes etc.

An example of a single landslide mapped at a basic level is shown in Figure 3.

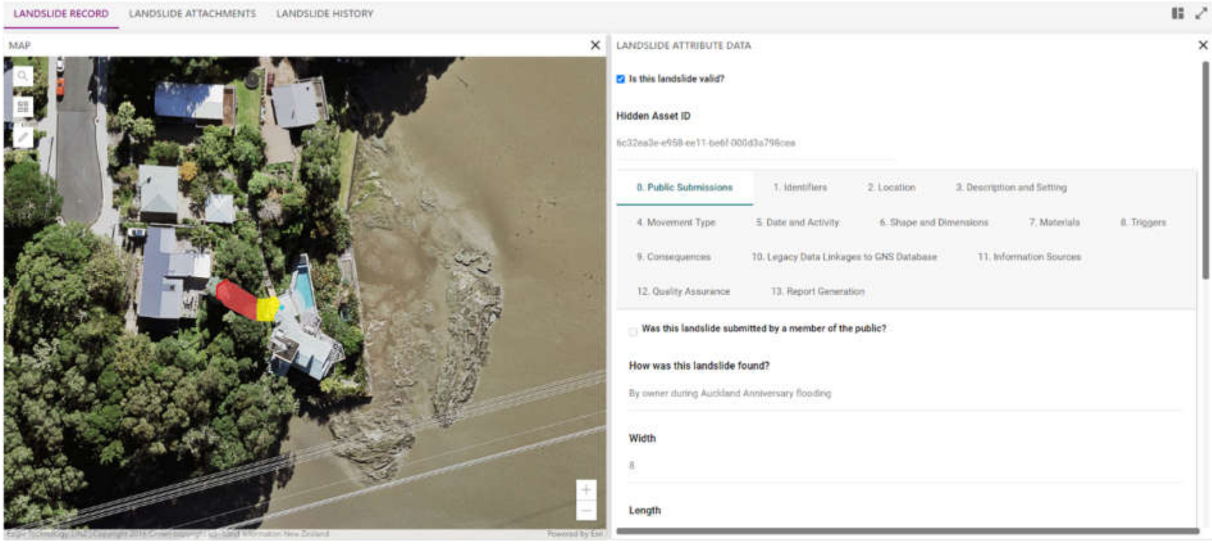

Figure 2. View of the NZ Landslide Database, showing the overview map of a single landslide. Red is zone of depletion, yellow is zone of accumulation. (OpenStreetMap / Auckland Council).

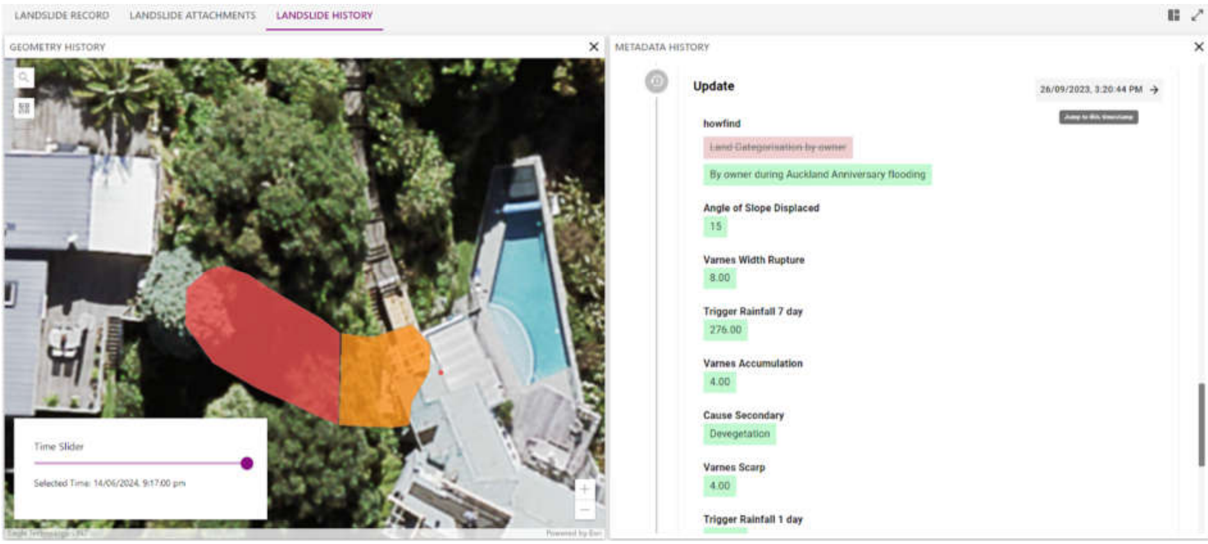

Figure 3. An example of the history log showing tracked changes. New data in fields is shown in green, and old/amended data in red. The data, including GIS shapes, can be tracked over time and rolled-back to previous versions. The time slider shows how geospatial features have changed.

3 Use in Emergency Response and Recovery

The NZ Landslides Database went live in late 2022. January 2023 was Auckland’s wettest month since records began. The heaviest rainfall produced widespread flooding across Auckland on Friday 27 January, which the National Institute of Water and Atmospheric Research (NIWA) described as at least a 1-in-200-year event. On that day, Auckland's Albert Park recorded 280 mm of rain in under 24 hours and 211 mm in under 6 hours. Central Auckland experienced over 45% of its yearly rainfall in just one month, over 8.5 times the January average (NIWA, 2023). Two weeks later in the early hours of 14 February 2023, a second weather event, Cyclone Gabrielle, hit Auckland. The storm continued south, affecting many other areas along the east coast of the North Island of New Zealand. A National State of Emergency was declared on 14 February (Roberts et al, 2024). During the Auckland floods in January and February 2023 the database was fully functional and provided a critical intelligence gathering function.

Figure 4. NZ Landslide Database feed on an Emergency Control Centre display during emergency response.

A live data feed from the NZ Landslides Database provided through an API enabled a map to be shown in the Auckland Emergency Management Emergency Control Centre (Fig 4). This displayed public reports of landslides in real time. Members of the public submitted 118 landslides through the public reporting tool during the 27 January to 14 February period in the Auckland region.

Figure 5. Example NZ Landslide Database automatically generated report.

This feed greatly added to situational awareness in the control centre, enabling prioritisation of emergency response and allowing the Controller to understand which areas were worst affected.
Once the emergency response was completed, more comprehensive data collection commenced. A combination of satellite imagery, aerial photography, LiDAR, and detailed on-site assessments are being used to validate public reports, to add technical detail to these reports, and to add landslides where no report was made. Detailed assessments were made of over 250 landslide affected homes. Each of these was mapped directly into the database, and the reports automatically generated from the database to ensure consistency and improve efficiency (Fig 5).

4 Need for an international data schema

There are few international landslide databases available. A prime example is the NASA Cooperative Open Online Landslide Repository (e.g. Juang et al, 2019) (Fig 6).

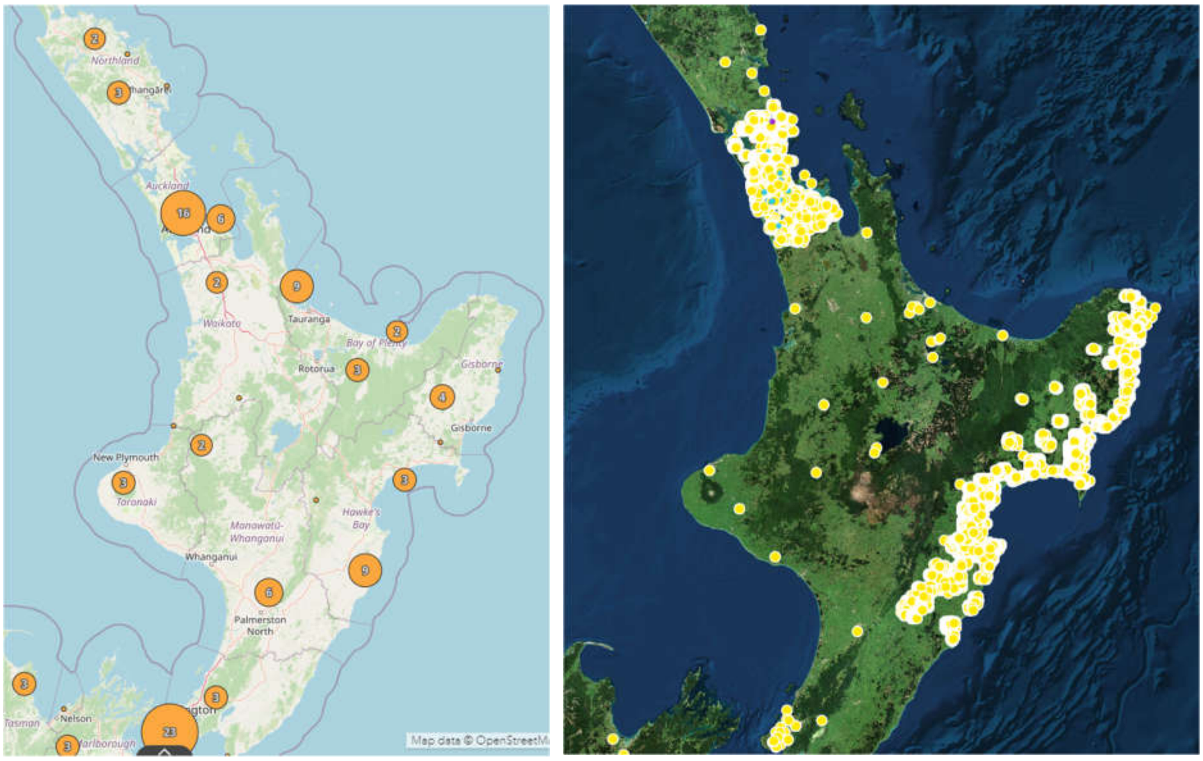

Figure 6. Comparison of the NASA Landslide Viewer (left) showing 56 landslides on the North Island of New Zealand and the NZ Landslide Database showing 150,000 landslides in the same area.

Efforts to develop landslide susceptibility and risk maps, and to eventually forecast landslides, will reply on reliable, consistent and comprehensive landslide inventories. Current approaches result in fragmented databases which suit the needs of the creators of those databases but may hamper these broader risk management needs. Experience from the geotechnical sector suggests that the benefits of these customised databases can be maintained while still allowing data to be transferred between databases by use of a standardised data transfer format such as AGS4.0 (NZGS, 2017 and AGS, 2017).

5 Conclusions

The New Zealand Landslides Database went live in 2022, and has already proved to be extremely valuable through the flooding and cyclone events in Auckland in early 2023. The database enables the crowd-sourcing of information from the public, with robust follow-up quality assurance, and the ability for input from skilled and experienced geo-professionals regardless of their organisation. This information has already proven valuable in emergency response and is showing great promise for recovery. It is anticipated that the comprehensive coverage that it provides will prove to be an extremely valuable tool in future landslide susceptibility, hazard and risk studies.

It is expected that the data collected through the Auckland flooding and cyclone events will be used to inform rainfall induced landslide modelling by GNS Science that will result in a landslide forecasting tool for use in emergency preparation (pers. comm.). However, international attempts to develop similar tools will be hindered until a consistently used data format or data transfer format is developed and adopted.

Acknowledgements

The database is co-funded by EQC and Auckland Council. It was developed by Beca and was inspired by the work of Colin Mazengarb for Mineral Resources Tasmania. I would like to acknowledge:

- Jo Horrocks and Natalie Balfour of the Natural Hazards Commission (NHC Toka Tū Ake) for seeing the potential in this project.

- Sally Dellow, Brenda Rosser & Chris Massey of GNS Science for their advice and support.
- The steering committee and technical advisory group members: Daniel Rodriguez (KiwiRail), Stuart Finlan (Waka Kotahi NZTA), Steve Raynor (Tauranga City Council), Susan Tilsley (Beca), Tracy Howe (University of Auckland / NZ Geotechnical Database), Claudia Harford (Auckland Council), David Barrell (GNS Science), Kiran Saligame (MBIE), Lukas Janku (KiwiRail), Phil Mourot (Waikato Regional Council) and Roger Fairclough (NZ Lifelines Council / NZ Landslide Advisory Group).

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